Exxon Background Series

WORLD ENERGY OUTLOOK

December 1980

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A background paper prepared by the Corporate Planning and the Public Affairs Departments of Exxon Corporation in cooperation with other Exxon departments and affiliates.

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INTRODUCTION

Each year, Exxon Corporation prepares a new World Energy Outlook with the help of its affiliates around the world. The Outlook projects the supply and demand of all forms of commercial energy to provide Exxon and its affiliates with a consistent basis for planning. The projections are being made public in the hope that they will contribute to informed decisions on important energy policy issues.

This year's Outlook projects energy supply and demand through the year 2000. For the first time, the Outlook incorporates the Centrally Planned Economies (CPE) of the Union of Soviet Socialist Republics (USSR), People's Republic of China (PRC) and Eastern Europe. Previous Exxon World Energy Outlooks included only net energy flows to or from these countries—not the group's internal supply and demand balances. Inclusion of this group of countries, which produce and consume nearly one-third of the world's energy, provides a more complete basis for assessing worldwide energy prospects. While available information on energy in the CPE is not as extensive as it is for other areas, it is sufficient to permit broad analysis of likely future developments. However, in certain analyses for which the data are inadequate, the projections exclude the CPE.

References are also made in the text to other country groupings: industrial countries and developing countries (OPEC, other oil exporters, high-growth and low-growth). These groupings are defined in the Appendix on page 40.

This Outlook was prepared over a period of six months ending in October 1980. It is based on Exxon's projections of economic growth, assumptions regarding environmental and regulatory policies, and assessments of energy resource availability. It recognizes that there will be short-term disruptions in energy supply, resulting in periodic supply-demand imbalances. However, no provision has been made for major political upheavals, deep and prolonged recessions or excessively restrictive policies by producing or consuming countries, any of which could alter the projected trends.

The energy supply and demand trends projected in the Outlook are consistent with an increase in the real cost of most forms of energy during the outlook period. Specifically, the trends are consistent with an increase in the purchase prices of Middle East crude oil of about 50 percent in real terms between 1980 and 2000. This scenario is reasonably similar to the "Middle Oil Price Case" in the 1979 Annual Report to Congress by the Energy Information Administration of the U.S. Department of Energy, issued in July 1980.

Coal prices also are assumed to increase in real terms, but coal is expected to be economically more attractive than oil in a number of uses. While the real prices of natural gas, too, are assumed to rise, gas prices are likely to show different relationships to oil and coal prices in different countries, depending on the uses of natural gas and the prices of alternative fuels for those uses.

Factors that shaped the Outlook continue to change. The supply-demand balances do not take into account, for example, the potential effects of tax changes proposed in the Fall of 1980 by the governments of Canada and the United Kingdom, the change in Administration in the United States in January 1981, or possible longer-term consequences of the Iran / Iraq conflict.

The Outlook does not try to encompass all possible outcomes of the political, economic, social and technological developments which could occur. The Outlook therefore represents a *plausible* future—but not the only *possible* future.

The rapid increase in world oil prices beginning in the early 1970s marked the start of a major transition in energy supply and use patterns. This transition is expected to culminate ultimately in the widespread use of sophisticated renewable energy sources, such as nuclear fusion and solar energy. In the absence of unexpected technological breakthroughs, however, widespread commercial application of such sources is at least several decades away. In the interim, world energy demand will have to be met predominantly by non-renewable fossil fuels and nuclear energy.

In the energy transition expected during the rest of this century:

Economic growth will be significantly lower than in the 1965 to 1973 period and slightly lower than the 1973 to 1979 experience. Adjusted for inflation, the world economy as a whole is expected to grow about 3 percent annually between 1979 and 2000, compared to more than 5 percent per year between 1965 and 1973.

Real energy costs are likely to rise throughout the period as a result of a limited supply of conventional oil and the high cost of most alternate energy sources.

World energy demand is expected to grow about 2½ percent per year, less than world economic growth and less than half the 1965 to 1973 energy growth rate. Even at this lower growth rate, world energy demand will increase 65 percent by the year 2000.

Only a modest increase in world production of conventional oil is anticipated. Volumes available for international trade are projected to show a net decline as oil-exporting countries increase domestic consumption. Consequently, the industrial countries no longer can rely on conventional oil for increases in their energy requirements.

Most of the growth in the industrial, residential and commercial sectors, where consumers have a choice of fuels, is projected to come from coal and from nuclear energy.

Oil use will be concentrated increasingly in specialized applications, including transportation, specialty products, such as lubricants, and some other demands for which large-scale substitution of other fuels is not practicable during the outlook period.

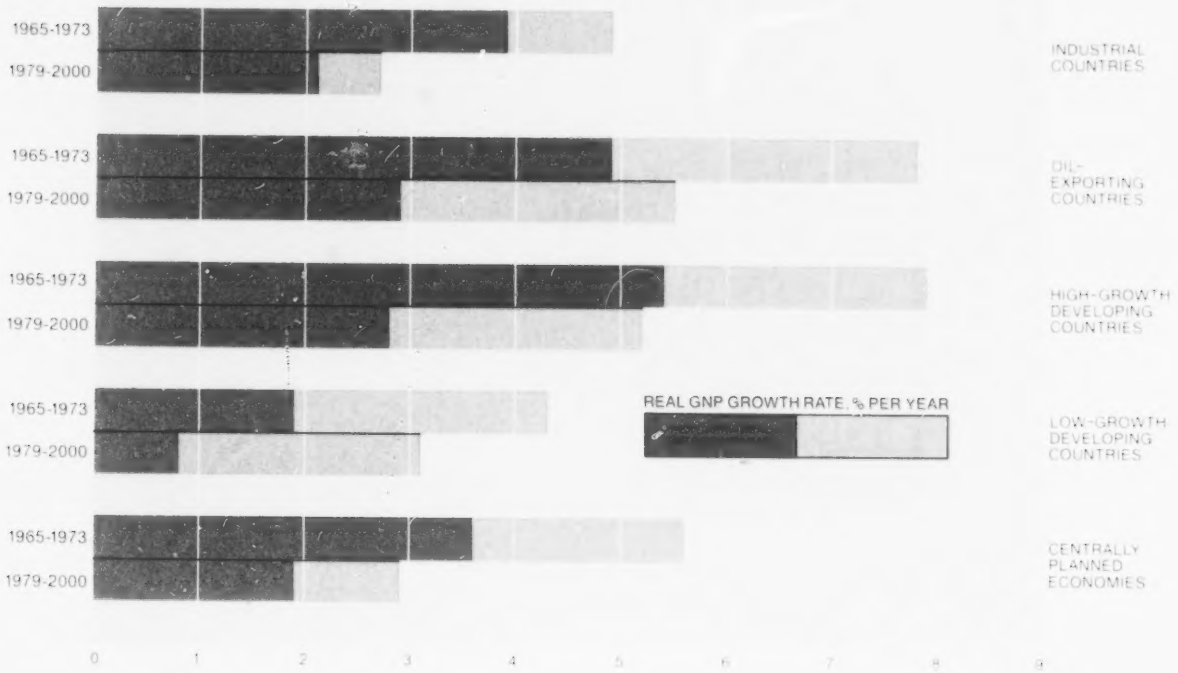
Production of synthetic fuels, especially liquids, will be needed during the late 1980s and in the 1990s to meet demands for transportation and other uses for which fuel substitution opportunities are limited.

The Outlook indicates that this transition to less intensive use of energy and reduced dependence on oil is achievable, but that it will not be easy. The world, and the industrial countries in particular, will remain dependent on internationally traded oil for many years—thus remaining vulnerable to oil supply disruptions. The investments necessary to develop new energy sources will be massive and will be dependent on achieving a public consensus on how best to balance economic, energy, environmental and other goals.

Given the long lead-times required for the construction or conversion of energy facilities and the development of new technologies, policy decisions and major investments will have to be made soon if the transition is to be accomplished in an efficient manner.

CHART 1

WORLD ECONOMIC GROWTH RATES



An average real growth in world gross national product (GNP) of about 3 percent per year from 1979 to 2000 underlies this Outlook. This projected rate is well below the 5 percent annual rate of the 1965 to 1973 period and slightly less than the rate experienced since 1973. It reflects slower growth of the work force, reduced future productivity gains and rising energy costs.

Chart 1 contrasts historical and projected growth rates for specified groups of countries. The total length of each bar represents average annual growth in total real GNP while the left-hand portion indicates the projected increase in real GNP per capita. As the top bar shows, the real GNP of the industrial countries grew about 5 percent per year from 1965 to 1973, well below the nearly 8 percent annual rate of both the oil exporters and the high-growth developing countries but somewhat above the 4 to 5 percent per year rate for the low-growth developing countries.

For the 1979 to 2000 outlook period, all country groups are expected to experience slower growth than between 1965 and 1973. The industrial countries are expected to grow about 2½ percent per year, the high-growth developing countries and oil-exporting countries at 5 to 6 percent per year and the low-growth developing countries at around 3 percent per year.

Although the CPE do not use comparable GNP accounts, rough estimates are included for this group. Growth in their combined GNP also is expected to be slower in the years ahead than in the 1965 to 1973 period.

The industrial countries, the oil-exporting countries and the high-growth developing countries all are anticipated to experience growth in real GNP per capita in the 2 to 3 percent per year range. Real GNP per capita in the low-growth developing countries is projected to increase less than 1 percent per year.

The major industrial countries have been reducing the energy intensity of their economies since the early 1970s, progressively consuming less energy per unit of economic output (GNP). Reductions in energy intensity can occur because of energy efficiency improvements (performing the same task with less energy), energy conservation measures (doing with less) and changes in the mix of goods and services produced by an economy. All of these factors contribute to the projections shown in this Outlook.

Reductions in energy intensity were stimulated by the sharp increases in oil prices starting in the early 1970s. In the United States, about 6½ barrels of oil equivalent[1] were consumed per $1000 of GNP (in 1979 dollars) in the 1960s. By 1979, 7 percent less energy was required per unit of GNP than the 1960 to 1969 average. In both Europe and Japan, the 1960 to 1969 average energy/GNP ratio was in the range of 3½ to 4 barrels of oil equivalent per unit of economic output. By 1979, the relative decline in energy intensity in Japan was similar to the U.S., about 9 percent less than the 1960 to 1969 average. In Europe, the 2 percent reduction by 1979 was much more moderate.

As depicted in Chart 2, further reductions in energy intensity are expected in the major industrial countries. The energy/GNP ratio projections shown are not assumptions, but results of the outlook analysis of economic growth and energy consumption patterns, energy policy decisions, the effect of higher prices and anticipated technological improvements.

U.S. energy consumption per $1000 (1979 dollars) of GNP is projected to be about 4¼ barrels of oil equivalent by 2000, or 33 percent less than the 1960 to 1969 average level. The European ratio is projected to decline more slowly, reaching a level of about 3 barrels of oil equivalent by 2000, 19 percent less than the 1960 to 1969 average. The energy/GNP ratio for Japan is expected to be about 2¼ barrels of oil equivalent by 2000, about 39 percent less than the historical average level.

In Canada, energy consumption per unit of GNP was 3 percent higher in 1979 than the average level of the 1960 to 1969 period. This rising trend is expected to continue through the early 1980s. It reflects both the government's policy of keeping energy prices below world levels and expanded activity in several energy-intensive industries made possible by Canada's adequate supplies of natural gas and electricity. By the mid-1980s, energy intensity in Canada also is expected to decline, and by 2000 it is expected to be 13 percent lower than the 1960 to 1969 average level. Throughout the outlook period, however, energy intensity in Canada will remain greater than in any other major industrial area.

Because of physical and social differences, the energy/GNP ratios of various regions cannot be expected to equal one another, particularly in the short run. Such factors as climate, population density, typical travel distance, age and mix of capital stock, and life styles account for these differences and many of these factors change very slowly, if at all.

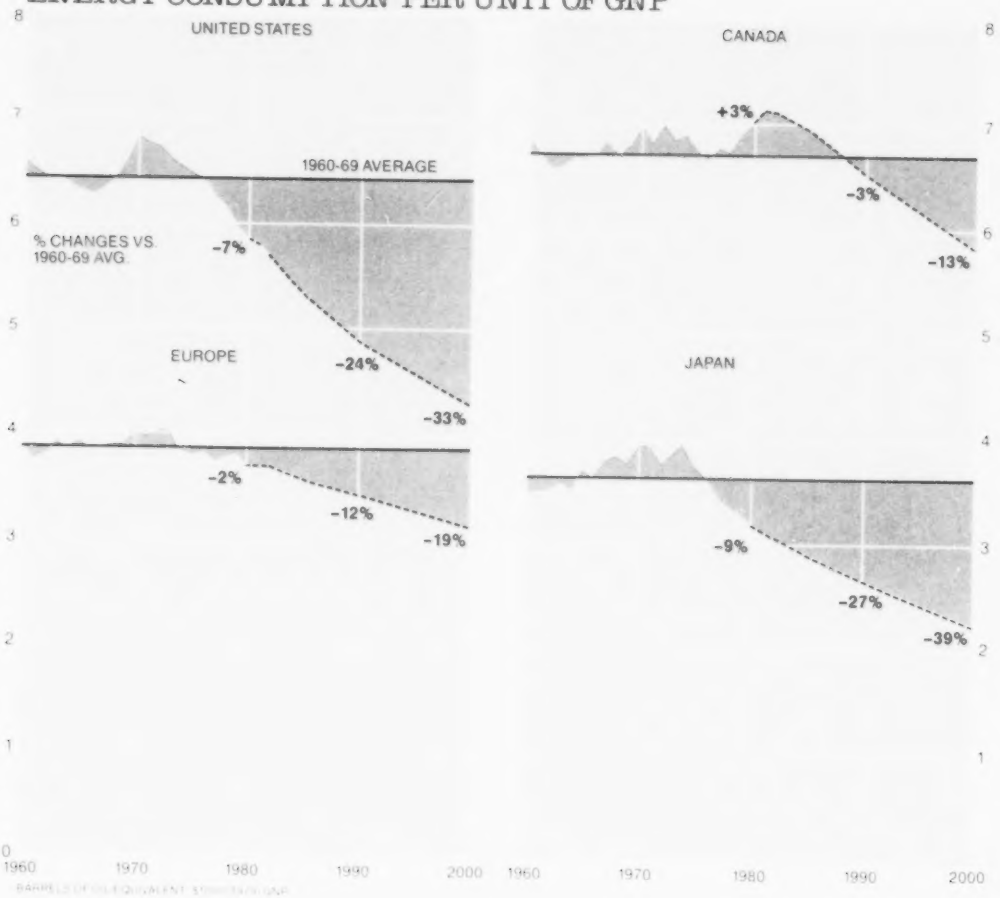
Nevertheless, there is major potential for energy saving. The projected total reduction in energy intensity in the major industrial nations amounts to savings of about 20 million barrels per day oil equivalent by 1990 and 40 million barrels per day by 2000 relative to the level of energy usage that would exist if the average level of energy use per unit of GNP which prevailed in the 1960s were to continue.

The following table shows, for the U.S., Europe and Japan, estimated changes in energy intensity for the major energy demand sectors.

[1] In this Outlook, demand and supply of fuels other than oil and natural gas liquids have been converted to oil equivalents using appropriate heating values for these fuels.

CHART 2

ENERGY CONSUMPTION PER UNIT OF GNP



SECTOR ENERGY CONSUMPTION PER UNIT OF GNP: PERCENTAGE REDUCTION (INCREASE) VS. PAST TREND

	1979	2000
UNITED STATES		
Transportation	3	44
Residential/Commercial	6	37
Industrial	15	29
Overall	7	33
EUROPE		
Transportation	(5)	17
Residential/Commercial	3	20
Industrial	10	22
Overall	2	19
JAPAN		
Transportation	11	48
Residential/Commercial	(11)	6
Industrial	17	46
Overall	9	39

In the United States, reductions in energy intensity to date have occurred in each of the demand sectors, but have been most significant in the industrial sector, largely reflecting conservation measures and retrofitting of existing facilities with more energy-efficient equipment. By 2000, however, improvements in the transportation sector are expected to lead the way as the U.S. moves toward smaller and more efficient automobiles. Further industrial sector improvements will depend primarily on continued retrofitting in the 1980s, with the application of new technology becoming a major factor in the 1990s. Projected reduced energy requirements in residential and commercial uses anticipate less generous space conditioning, continued retrofitting of existing structures, and more efficient new structures and appliances.

In Europe, reductions to date in energy intensity also have been most pronounced in the industrial sector. While energy intensity in the transportation sector has increased since the 1960s, improvements by 2000 are expected to reach about 20 percent, roughly comparable to energy intensity reductions in the other two energy use sectors.

Substantial reductions in energy intensity are expected in both the transportation and industrial sectors in Japan. However, given the share of the industrial sector in Japan's total energy demand (about 60 percent), improvements in that sector have by far the greatest potential for energy savings. Structural changes in the Japanese economy, including reduced emphasis on such energy-intensive industries as steel, shipbuilding and petrochemicals, are expected to result in lower energy/GNP ratios for Japan than would otherwise be possible. The residential and commercial sector accounts for a relatively small share of total demand, and the aggregate energy savings are expected to be small compared to those in either the transportation or industrial sectors.

Total world demand for energy is projected to grow about 2½ percent per year through 2000, less than half the 1965 to 1973 rate. The reduced rate reflects both slower economic growth and a reduction in energy intensity attributable to increased efficiency in the use of energy, to conservation and to a change in the mix of goods and services produced in the world.

Even at this low growth rate, energy demand is projected to increase about 65 percent, rising from almost 140 million barrels per day oil equivalent in 1979 to 225 million barrels per day by 2000.

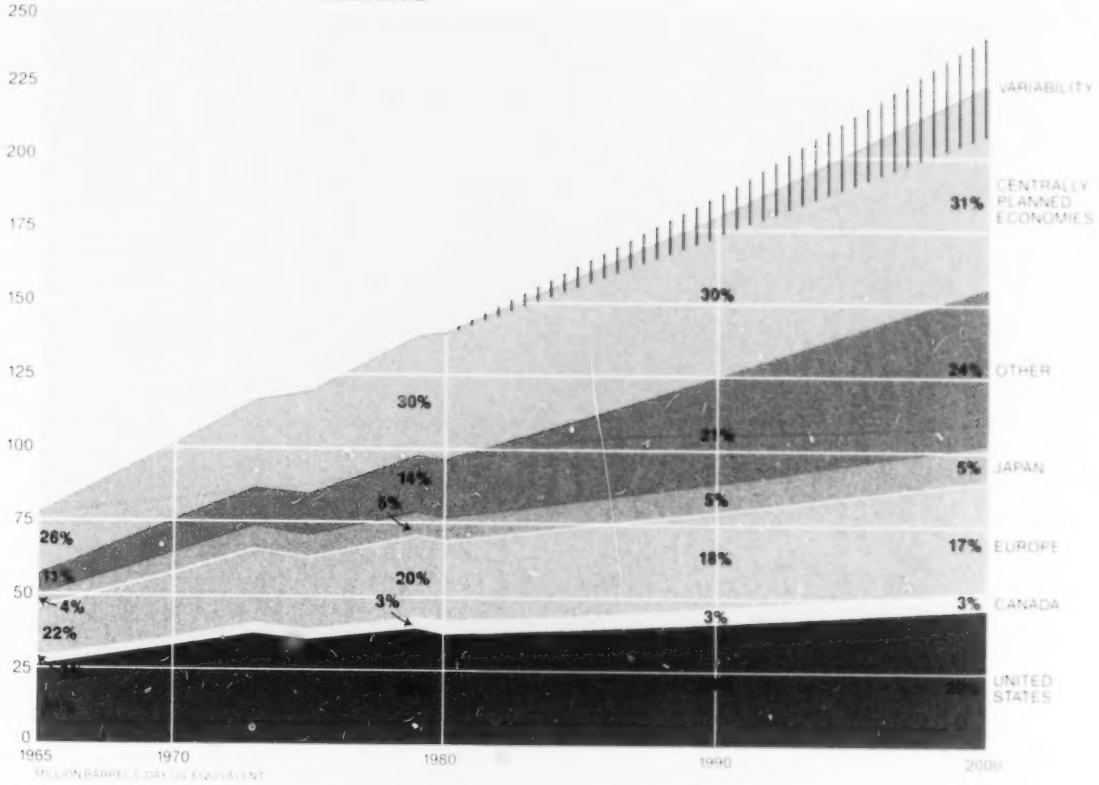
The following table summarizes projected energy demand growth rates for the areas shown on Chart 3.

ENERGY DEMAND GROWTH, PERCENT PER YEAR

	1965-1973	1973-1979	1979-2000
United States	4.3	0.8	0.8
Canada	5.9	3.3	2.1
Europe	5.1	1.5	1.5
Japan	11.4	1.4	2.1
Industrial Countries	5.2	1.2	1.2
Other	6.9	5.3	4.9
CPE	5.1	5.6	2.6
Total	5.3	2.9	2.4

CHART 3

WORLD ENERGY DEMAND



The aggregate growth rate for the four major industrial areas is expected to drop significantly to just over 1 percent per year, about one-quarter of the pre-1973 rate. The U.S. growth rate will be the lowest, averaging less than 1 percent per year. European demand is projected to rise at a steady, but modest $1\frac{1}{2}$ percent annual rate. In Canada, energy demand is expected to grow somewhat faster, at about 2 percent per year, largely because of relatively low energy prices. Demand in Japan is likely to rise about 2 percent per year as a result of continued strong economic growth.

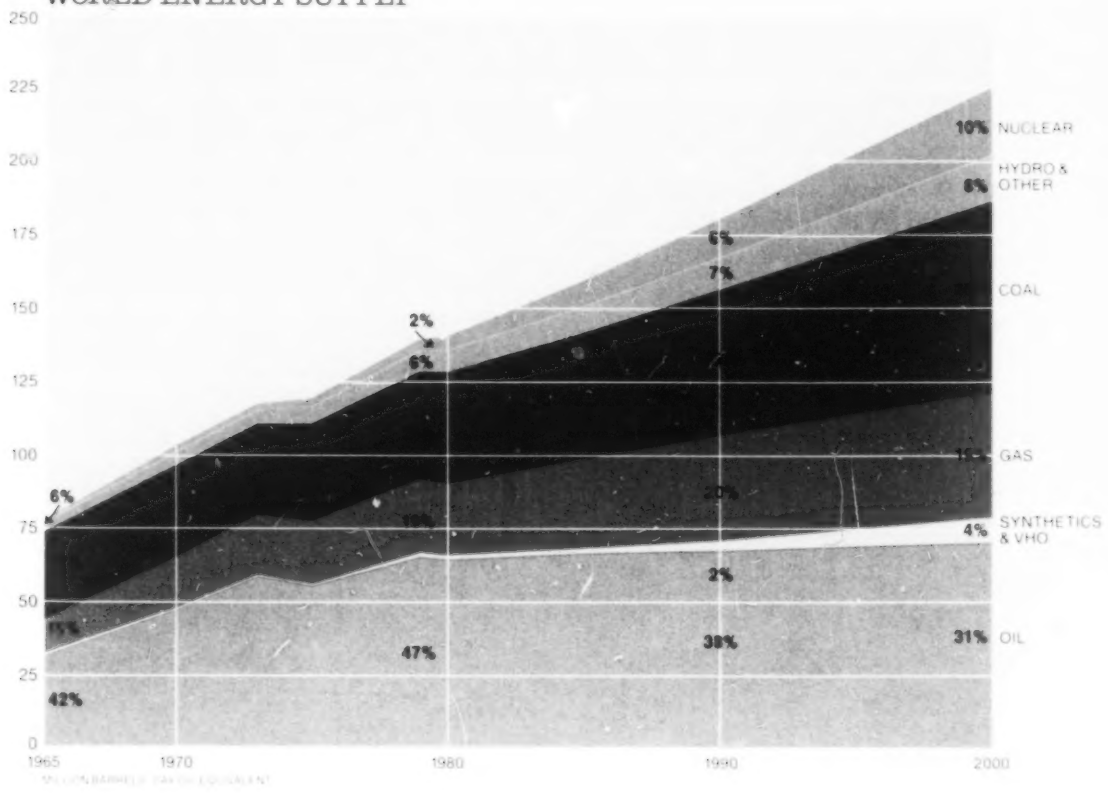
The CPE are expected to maintain their current 30 percent share of world energy demand throughout the outlook period. Their demand growth rate is projected to slow to $2\frac{1}{2}$ percent per year, about half the historical rate.

Energy demand in the "Other" group, mainly developing countries, is projected to grow nearly 5 percent per year, tripling to over 50 million barrels per day oil equivalent by 2000. This group's share of world energy demand is expected to increase from 14 percent in 1979 to about 24 percent by 2000.

Energy demand may vary significantly from this projection if economic growth rates turn out to be different than projected, or if the projected improvements in energy efficiency prove incorrect. These factors can be affected by government energy policies and the rate of technological advancement. If economic growth rates, for example, were to vary by $\frac{1}{2}$ percent per year from those projected here, energy demand could vary by about plus or minus 7 million barrels per day oil equivalent in 1990 and by 17 million barrels per day in 2000. This variability is indicated by the hatched area, shown for convenience in aggregate, at the top of the chart.

CHART 4

WORLD ENERGY SUPPLY



For many years prior to 1973, oil and gas provided most of the growth in world energy supply. Oil penetrated all sectors of the world economy. Between 1965 and 1973, oil supply grew almost 8 percent per year and gas more than 7 percent, rates much higher than the rate at which total energy supply was increasing. By 1973, oil and gas accounted for two-thirds of total world energy supply

Developments since that year have set in motion a dramatic transition in the mix of primary fuels, as illustrated in Chart 4. Conventional oil supply is expected to grow less than 1 percent per year through 2000 resulting in a decline in oil's share of energy supply from 47 percent in 1979 to 31 percent by the year 2000. Most future energy growth will have to be supplied from other energy sources. All non-oil energy sources have projected growth rates above that for total energy supply, as shown in the table below.

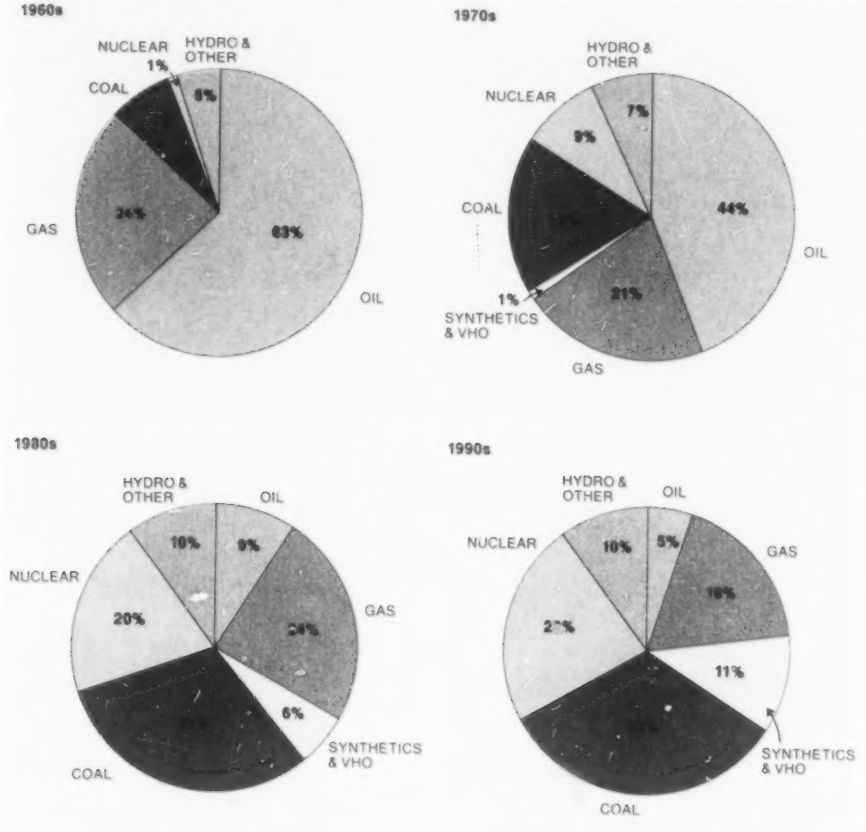
ENERGY SUPPLY GROWTH, PERCENT PER YEAR

	1965-1973	1973-1979	1979-2000
Oil	7.7	2.2	0.4
Synthetics & VHO	—	—	13.8
Gas	7.3	3.6	2.6
Coal	1.0	2.4	2.8
Nuclear	27.8	20.9	10.0
Hydro & Other	3.9	4.6	3.5
Total	5.3	2.9	2.4

Conventional natural gas supply is projected to keep pace with overall energy use, maintaining its share of world energy supply at about 20

CHART 5

PERCENTAGE SHARE OF GROWTH IN WORLD ENERGY SUPPLY



percent. In the 1990s, projected growth in world gas supply will require the development of reserves in remote areas and the construction of expensive distribution systems to bring the gas to markets. Given favorable prices and supportive government policies, the necessary volumes should be available. Indeed, world gas reserves in the 1990s would probably be sufficient to support consumption above projected levels, should conditions prove to be more favorable than assumed in the Outlook.

Coal, which grew slowly between 1965 and 1973, is projected to be a major source of energy supply growth. Coal is expected not only to meet a substantial share of new energy demand, but also to replace oil and gas in major industrial and electric utility markets. Coal use is projected to grow almost 3 percent per year, increasing its share of world energy supply from 26 percent in 1979 to 28 percent by 2000. (If the coal converted to synthetic oil and gas were included here, coal's share would increase to 30 percent by 2000.) At that level, coal will rival oil as the single largest source of energy, but world coal resources still would be large relative to production rates. Coal use is expected to be constrained by the growth in demand rather than by the availability of supply.

Most coal will continue to be consumed in the country in which it is produced, with the largest increases occurring in the United States and the CPE. Some countries, however—particularly in Europe and East Asia—are likely to import substantial volumes of coal. Exports from Australia, South Africa, Colombia, the U.S. and other coal producers are likely to increase rap-

idly. In fact, seaborne coal trade is expected to quadruple by 2000 to over 600 million metric tons hard coal equivalent per year (almost 8 million barrels per day oil equivalent).

Nuclear energy is expected to increase sevenfold over the outlook period, with growth averaging 10 percent per year. As a result, its share of total energy supply will increase to 10 percent by 2000, up from just 2 percent in 1979. Nuclear energy is the most economic form of base-load electricity generation in most locations. This strong economic incentive, if combined with resolution of presently perceived environmental and safety concerns, could lead to higher rates of nuclear energy growth. On the other hand, further licensing or other delays could result in less nuclear energy than indicated in the Outlook.

The "hydropower and other" category of total energy supply is projected to increase from 6 percent in 1979 to 8 percent by the year 2000. Over 40 percent of the growth in this sector is expected to be in Latin America, concentrated in a relatively small number of hydropower sites with very large potential. Other significant hydropower additions are expected in Canada and the USSR. In the U.S., hydropower expansion will come principally from a large number of small and low-head systems. Geothermal and solar energy are the principal components of the "other" sources. Ocean thermal electricity, wind, wave and tidal power are included as well but in extremely small amounts.

By the 1990s, synthetic fuels and very heavy oil (VHO) are expected to become a major source of supply growth, primarily in the U.S., but also in Canada, Brazil, Venezuela, Australia, and a few other countries. From a negligible level at present, synthetic fuels and VHO are projected to supply 2 percent of total world demand by 1990 and 4 percent by 2000. This implies a total production of almost 8 million barrels per day oil equivalent by 2000, including more than 6 million barrels per day of liquids.

The changing patterns of world energy supply growth are illustrated in Chart 5, which shows graphically the drop in oil's share of total growth over four decades—as well as the significant increases in the shares of growth to be provided by coal and nuclear in the two decades ahead.

Electricity use in the world outside Africa, Middle East and CPE is projected to grow 3 percent per year from 1979 to 2000, faster than total energy, but only half the average rate of the 1960 to 1979 period. The slower rate of growth in electricity use is in line with the lower growth in overall energy use.

The sharp reduction from historical growth rates is attributable mainly to the U.S., Canada, Europe and Japan. For this group of countries, growth in electricity use is projected to average 2½ percent per year to 2000. Latin America and the Far East other than Japan are projected to maintain electricity growth rates of about 6 percent per year between 1979 and 2000. The major industrial countries, which accounted for 85 percent of electricity consumption in 1979, will still account for 75 percent by 2000.

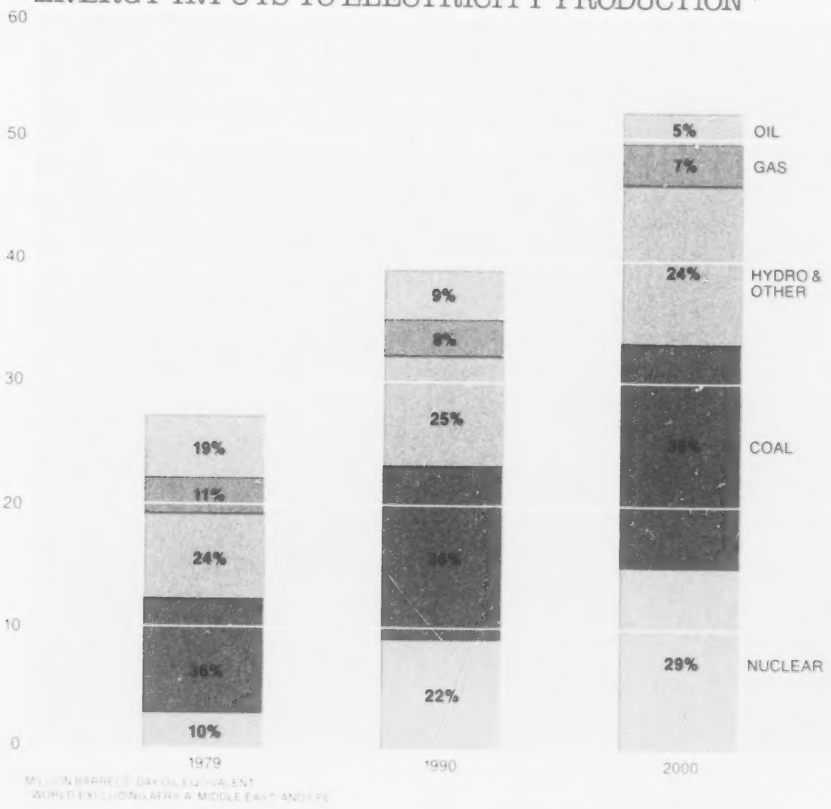
In the major industrial countries, electricity demand growth in the residential and commercial sector averaged almost 9 percent per year during the 1965 to 1973 period. The high growth rate was largely attributable to rapid increases in lighting standards, appliances and air conditioning where few practical alternatives to electricity existed. In the future, approaching market saturation and improved efficiency will reduce growth in electricity use in appliances and air conditioning. However, electric heating use, particularly with efficient heat pumps, will be increasing. The net effect of these changing patterns will be electricity growth rates for residential and commercial uses in the U.S. and Europe—the two major consuming areas—of 1½ percent and 3 percent per year, respectively, during the outlook period.

Electricity consumption in the industrial sector will grow more slowly than in the past, due to projected lower rates of economic growth, increased efficiency in energy use and the shifts towards less energy intensive goods and services. Historical growth in the industrial sector averaged about 6 percent per year in the United States and Europe. Over the next 20 years, the pace in these areas is expected to fall to 2 percent and 2½ percent per year, respectively.

Chart 6 illustrates the changing pattern of fuel supplies for electric power generation. Nuclear power generation, for most locations the lowest cost source of base-load electric power today, is projected to supply almost half the growth in

CHART 6

ENERGY INPUTS TO ELECTRICITY PRODUCTION *



electricity to 2000, increasing its share to 29 percent. In some areas, however, particularly the United States, the growth of nuclear energy will be limited by siting problems, perceived economic risks to utility companies stemming from regulatory uncertainty, long lead-times and in some cases, the need for "load-following" capability – that is, varying production of electricity more in line with normal fluctuations in demand. In these cases, coal is probably the preferred alternative. Coal, therefore, is expected to continue as the largest fuel source for electric power generation, supplying about 35 percent of needs throughout the outlook period. Coal-fired plants can be used not only for base-load but also for intermediate-load electric power generation where flexibility is needed.

Hydropower and geothermal are limited by the availability of sites. Increases over the outlook period will be concentrated in a small number of large projects, primarily in Latin America and Canada, where hydropower is projected to supply about 60 percent and 50 percent, respectively, of electric power requirements by 2000. Increases also are projected in the United States and the USSR.

The transition away from oil and gas in electricity generation is clearly evident. Their share is projected to drop from 30 percent in 1979 to just over 10 percent by 2000. In the industrial countries, oil input by 2000 is projected at about 1½ million barrels per day, a level that is near the estimated practical minimum, given demands in remote areas and "peaking" needs that cannot be met by pumped hydropower or other storage devices. Only in oil-exporting countries is the share of oil and gas used to generate electricity expected to increase.

Chart 7 displays the projected world supply of nuclear energy over the next two decades.

In the past several years, perceptions of future electricity demand growth have moderated. This, together with environmental constraints, large capital requirements, long lead-times, and limited capability for using nuclear energy for "load-following" applications, has caused some utilities to back away from nuclear expansion plans.

The economic incentive for electric power generation by means of nuclear energy remains strong, however. The projection shown here is based on the assessment that nuclear is, and will continue to be, the lowest cost source of base-load electric power. It is projected to be the fastest growing major energy source, expanding at a 13 percent annual rate in the 1980s and 6½ percent per year in the 1990s. Its share of world energy supply will be about 10 percent by 2000 and its share of electric power generation, 39 percent.

Over the outlook period, the predominant share of nuclear generating capacity – which is projected to exceed 800 gigawatts (billions of watts) by 2000 – will be in the major industrial areas of the world, as indicated in the table. Most of the European and all of the U.S. capacity projected for 1990 is either operational today or under construction. About two-thirds of the Japanese capacity shown for 1990 is also operational or under construction, and most of the remaining one-third is on order. In the 1990s, 75 percent of the growth in nuclear capacity in the world other than the CPE is expected to be outside the U.S.

CURRENT OUTLOOK
INSTALLED CAPACITY – GIGAWATTS

	1979	1990	2000
United States	53	120	181
Europe	36	122	216
Japan	15	37	75
Other	8	42	105
CPE	15	95	226
Total	127	416	803

The CPE share of nuclear generating capacity is projected to increase from 12 percent of the world total in 1979 to almost 30 percent by 2000. Seventy percent of this growth is expected to be in the USSR, where nuclear's share of total energy supply by 2000 is projected to be roughly the same as in the U.S., about 11 percent.

Neither uranium supply nor enrichment capacity is expected to constrain nuclear growth. Uranium production from presently known reserves should be sufficient to meet requirements well into the 1990s, and additional reserves from new discoveries are expected to satisfy projected demands thereafter. Enrichment capacity will probably be in excess of needs throughout the outlook period.

CHART 7

WORLD NUCLEAR ENERGY SUPPLY

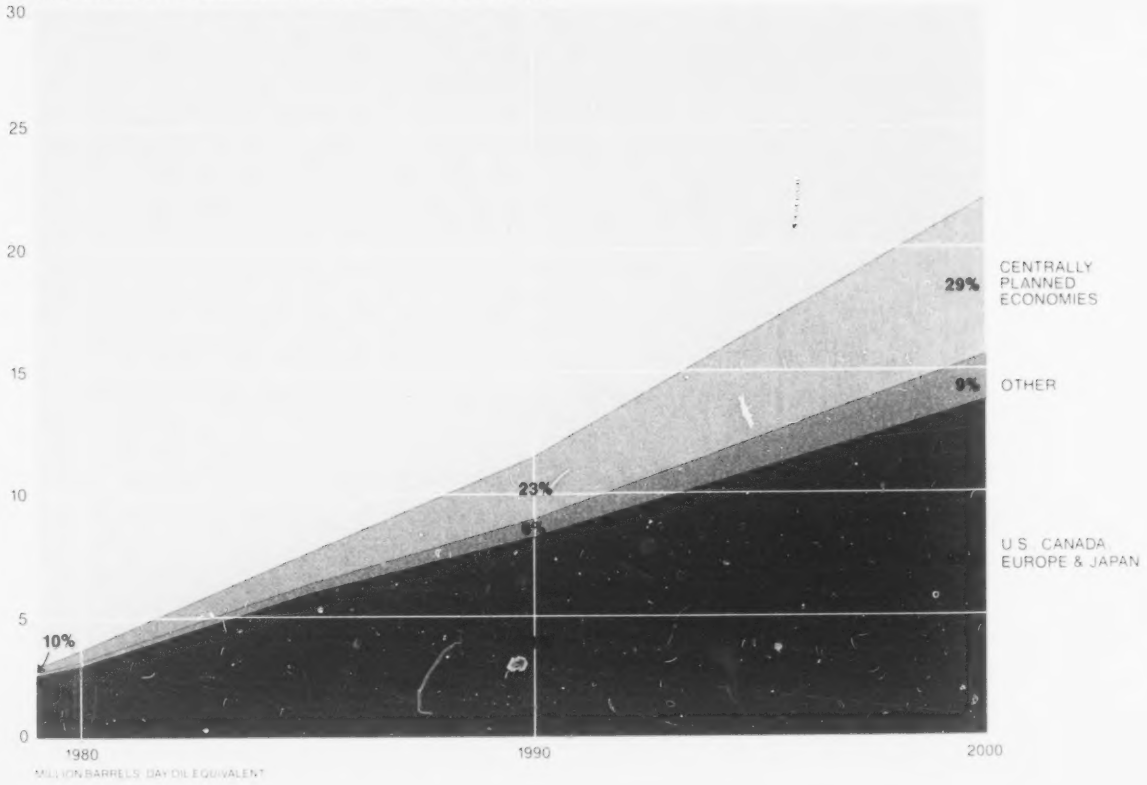
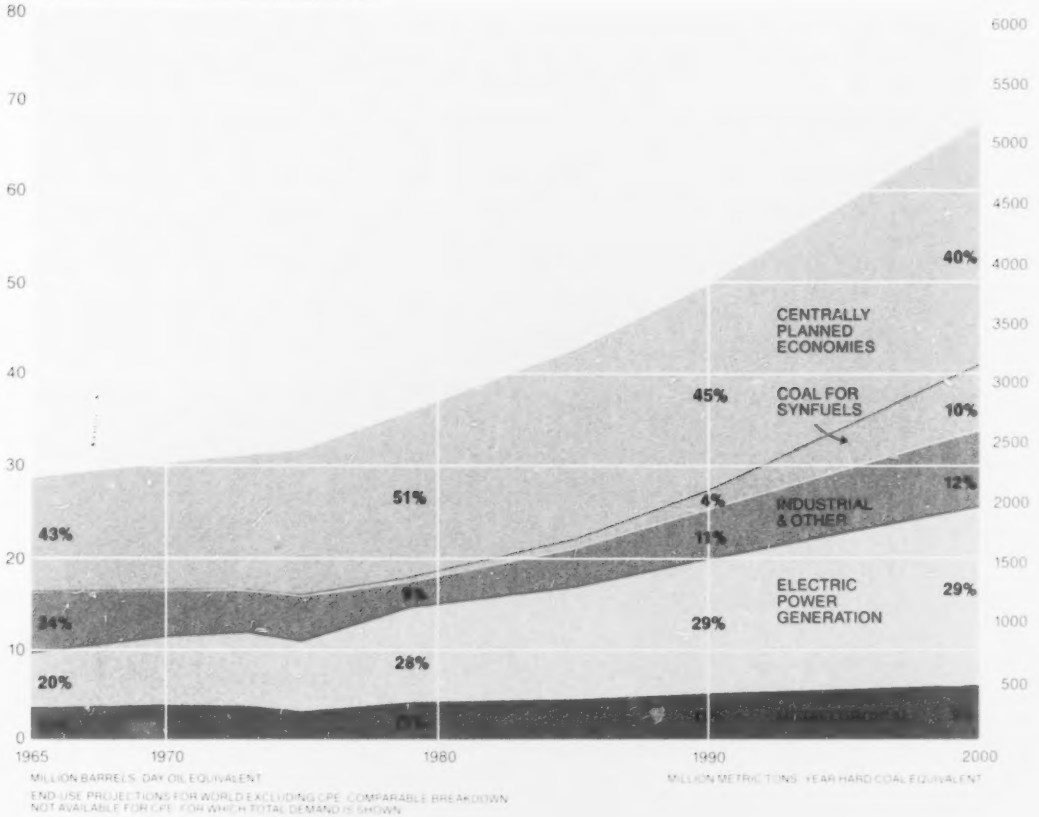


CHART 8

WORLD COAL DEMAND*



END-USE PROJECTIONS FOR WORLD EXCLUDING CPE. COMPARABLE BREAKDOWN NOT AVAILABLE FOR CPE, FOR WHICH TOTAL DEMAND IS SHOWN

Coal, the use of which was stagnant in the 1960s and actually declined during the early 1970s, is expected to be the single largest contributor to growth in world energy supply over the next two decades. World coal demand is projected to increase from 36 million barrels per day oil equivalent in 1979 to 68 million barrels per day by 2000, an annual growth rate of 3 percent.

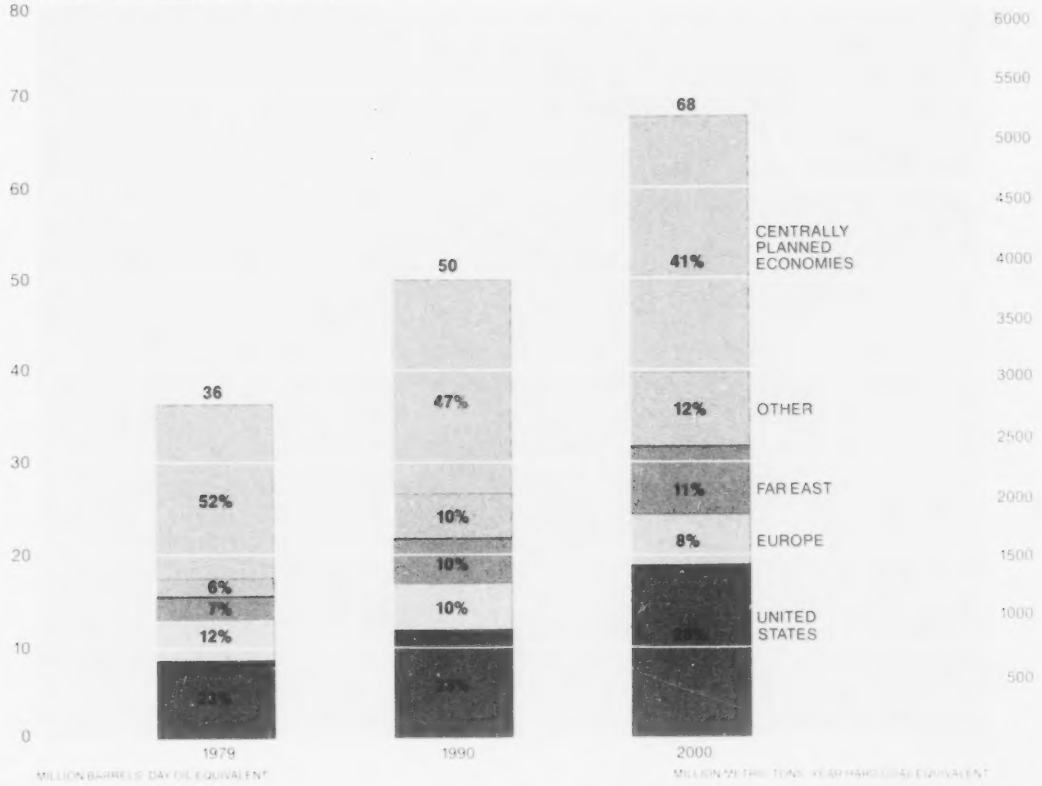
Among major consuming regions, the Far East and the United States are expected to lead in increases in coal demand with average growth rates of 5 percent and 4 percent per year, respectively. European demand is projected to grow more slowly at $2\frac{1}{2}$ percent per year. Coal use in the CPE is anticipated to rise less than 2 percent per year.

Chart 8 shows coal demand by end-use for the world, excluding the CPE. Data limitations preclude a comparable breakdown for demand in the CPE which, for completeness, is shown in total at the top of the chart. Outside the CPE, the primary market for coal will continue to be electric power generation. Future growth in this use, at an average rate of 3 percent per year, will be less than the $4\frac{1}{2}$ percent annual rate experienced in the 1965 to 1979 period, but still sufficient to double consumption by electric power stations by 2000. Metallurgical coal use is expected to increase only 2 percent per year.

Coal demand for industrial and other direct uses, which had been declining for many years, recently began to grow. Direct industrial use of coal is projected to increase about 6 percent per year over the outlook period. Industrial users building large new steam or heat facilities are increasingly finding coal an attractive alternative to other fuels.

CHART 9

WORLD COAL SUPPLY



In addition to these traditional uses, the conversion of coal to synthetic gas or liquid fuels is expected to accelerate beginning in the late 1980s. Along with oil shale, coal will become a principal contributor to the development of a major synthetic fuels industry in the United States, Brazil, and other countries, both as a feedstock and a fuel. A negligible amount of coal is currently used for synthetic fuels production, but by 2000 it is likely to account for 10 percent of world coal demand. The table summarizes the growth rate projections for world coal demand shown in Chart 8.

COAL DEMAND GROWTH, PERCENT PER YEAR

	1965-1973	1973-1979	1979-2000
Metallurgical	1.0	1.7	2.0
Electric Power	4.1	4.8	3.3
Industrial and other	(5.0)	(4.8)	4.6
Coal for Synfuels	–	–	20.6
World excluding CPE	–	1.4	4.1
CPE	2.3	3.5	1.8
Total	1.0	2.5	3.0

The greatest constraints on coal use will continue to arise from environmental limitations. Some accommodation of energy and environmental objectives will be required to achieve the projected coal use levels.

The CPE share of total coal supply is projected to decline over the outlook period, from more than 50 percent in 1979 to about 40 percent by 2000, as shown in Chart 9. Even so, net coal exports from the CPE to the rest of the world are expected to more than double over the outlook period.

The United States will continue to be the world's largest coal producer, its share of world

coal supply increasing from 23 percent in 1979 to about 28 percent by 2000. Europe's coal production is expected to increase very little over the period, despite a growing penetration of coal in the industrial and power generation sectors. Its share of world supplies will decline from 12 percent in 1979 to 8 percent by 2000. Three-fourths of the growth in Europe's coal demand is expected to be supplied by imports, as local production will meet only about 60 percent of local demand by 2000, compared to 80 percent in 1979.

Production capacity for export markets will increase in Australia, South Africa, and Colombia, as well as the United States, Canada, and the CPE. Major increases are anticipated in the amount of coal entering international trade. Seaborne coal trade is expected almost to quadruple from about 160 million metric tons hard coal equivalent (about 2 million barrels per day oil equivalent) in 1979 to over 600 million tons (almost 8 million barrels per day oil equivalent) by 2000, indicating considerable need for expanded transportation and port facilities.

World gas consumption is projected to increase less rapidly than in the past, averaging 2½ to 3 percent per year during the outlook period, compared with more than 7 percent per year between 1965 and 1973 and about 3½ percent annually during the 1973 to 1979 period. As Chart 10 shows, most of the growth is expected to occur outside the United States and Europe; their combined share of world gas demand is expected to decline from 55 percent in 1979 to less than 35 percent by 2000.

In Canada, which has large natural gas resources, demand growth is expected to be limited by available markets and to increase at a rate of only slightly more than 2 percent per year. Canada's share of world gas demand is projected to remain constant at 3 percent throughout the outlook period.

Elsewhere, growth will be rapid. Japanese consumption is projected to more than triple over the outlook period, its share of world demand rising from 2 percent in 1979 to 4 percent by 2000. In the developing countries, total gas demand is expected to increase more than 7 percent per year between 1979 and 2000, accounting for almost 40 percent of the growth in world gas demand. Developing countries with indigenous gas resources are expected to account for a major portion of the increase.

The largest share of projected growth in world gas demand, almost 50 percent of the total, is expected to be in the CPE, predominantly in the USSR. By 1990, the USSR is projected to be the world's largest producer and consumer of gas.

The table below shows projected growth rates for gas consumption in the major areas.

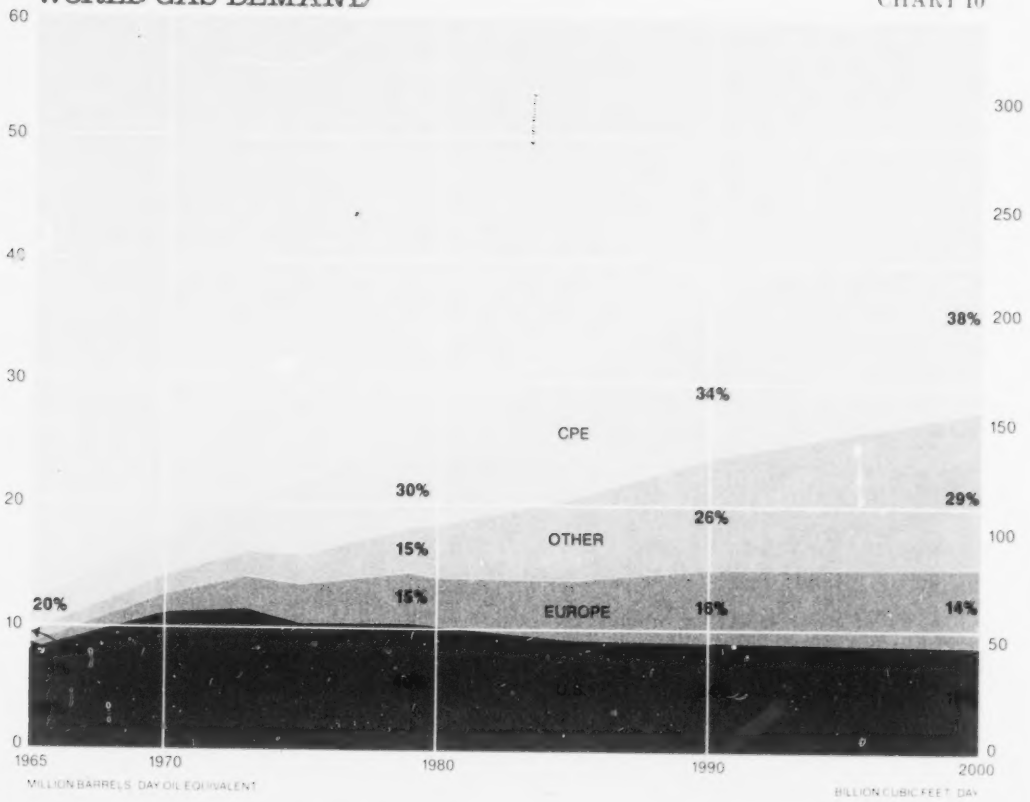
GAS DEMAND GROWTH, PERCENT PER YEAR

	1965-1973	1973-1979	1979-2000
United States	4.4	(1.8)	(0.9)
Europe	27.8	7.3	2.4
Japan	16.2	31.1	5.6
Other	9.9	8.5	6.0
CPE	8.8	8.9	3.9
Total	7.3	3.6	2.7

Chart 11 highlights the changing pattern of world gas production. U.S. natural gas production peaked in 1973 and has been declining

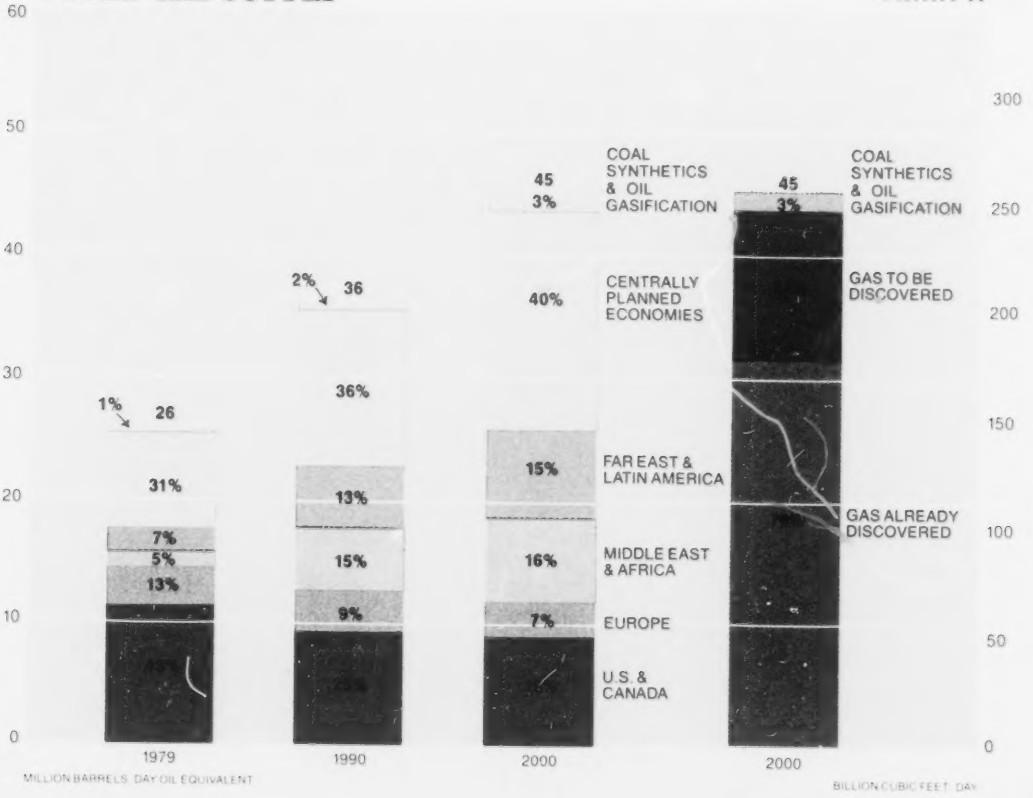
WORLD GAS DEMAND

CHART 10



WORLD GAS SUPPLY

CHART 11



since then. The downward trend is likely to be moderated in the mid-1980s with the completion of a pipeline from Alaska to the lower 48 states. Domestic natural gas production is supplemented by imports, primarily via pipeline from Canada and Mexico and liquefied natural gas (LNG) from North Africa. Synthetic gas will become important in the 1990s, providing nearly 10 percent of U.S. gas supply by 2000.

European production is expected to increase until the mid-1980s, reflecting increasing North Sea production. Thereafter, demand growth will be supplied by increased imports as indigenous production begins to decline. By 2000, about half of Europe's supplies will be from imports. While import contracts are firm through the mid-1980s, a major portion of the volumes projected for 2000 have yet to be contracted and development of major facilities will be required.

Japan relies almost entirely on imports for its gas requirements and these are projected to increase significantly, mostly from other countries within the Far East, but by the 1990s to a significant degree from the Middle East as well. Increases in gas movements to Japan are dependent upon investments for design and construction of large LNG facilities in the producing areas, as well as receiving and distribution facilities in Japan.

Elsewhere in the non-CPE world, a very large gas resource base exists, much of which already has been discovered. Substantial production increases from geographically remote regions in Latin America, Africa and the Far East, as well as from areas in the Middle East, are anticipated between 1979 and 2000. These increases presuppose the completion of a number of projects for utilizing local gas reserves. Even so, gas production in these areas is demand limited, and production levels could be higher should conditions for development be more favorable than assumed in the Outlook.

The bar at the right of Chart 11 shows gas supply in 2000 in terms of reserves already discovered and volumes which are expected to come from reserves yet to be discovered and from synthetic gas production. Virtually all of the synthetic gas volume must come from facilities yet to be built.

WORLD OIL DEMAND

Until the early 1970s, world oil demand expanded rapidly, growing at a rate substantially greater than that for total energy demand. Since 1973, however, growth has averaged only about 2 percent per year. Over the next 20 years, oil demand is expected to increase less than 1 percent per year, well below the rate for other forms of energy. This reversal will be most pronounced in the industrial countries, which in the past were chiefly responsible for the rapid expansion in oil demand.

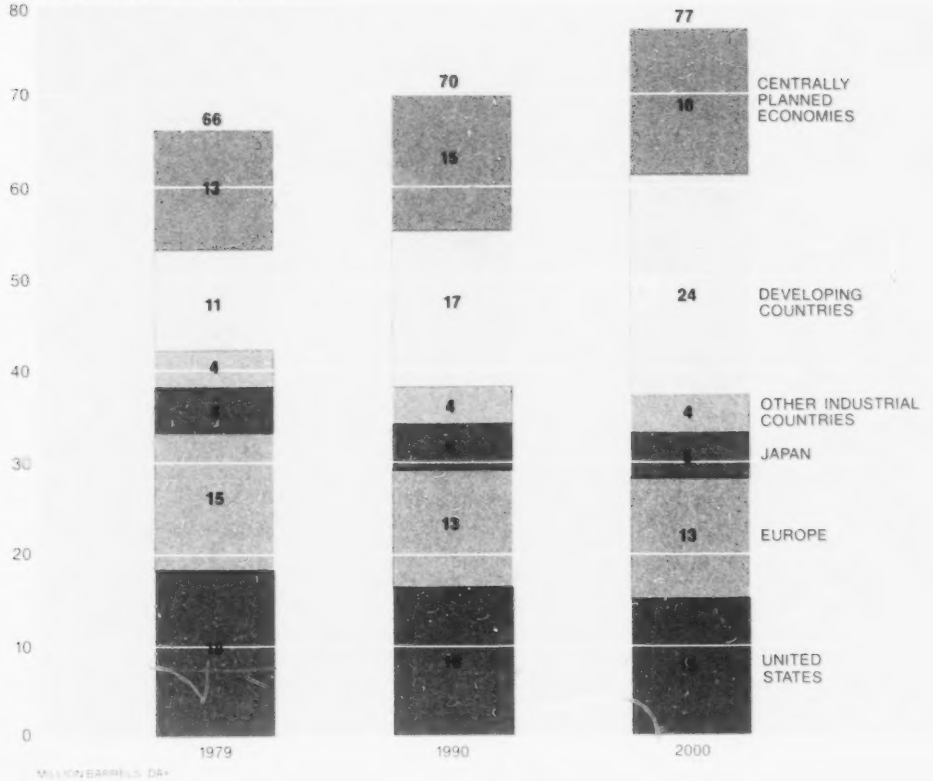
As shown in Chart 12, oil demand in the major industrial countries is projected to decline from about 40 million barrels per day in 1979 to about 35 million barrels per day by 2000, as a result of conservation, efficiency improvements and substitution of alternate fuels. The United States is expected to show the largest decline – from 18 to 15 million barrels per day. Europe is projected to decline in the 1980s – from 15 to 13 million barrels per day – and then to level off during the 1990s. Japan's demand is forecast to remain roughly constant at about 5 million barrels per day.

Oil consumption in the developing countries, on the other hand, is projected to grew about 4 percent annually, reaching almost 25 million barrels per day by the end of the century – about double the current level. Of this growth, 75 percent is expected to take place in the oil-exporting countries, many of which are pursuing industrialization policies designed to use a significant share of their energy resources.

Demand in the CPE is expected to increase about 1 percent annually – from 13 million barrels per day in 1979 to 16 million barrels per day by 2000 – with the PRC expanding at almost a 4 percent per year rate, the USSR at less than $\frac{1}{2}$ percent per year and Eastern Europe declining slightly.

CHART 12

WORLD OIL DEMAND



The reduction in oil demand in the major industrial countries will not occur equally in all sectors of their economies. Oil consumption will become increasingly concentrated in specialized applications – those uses in which substitution of other fuels is technically infeasible or economically prohibitive. The following table shows oil's contribution to total energy demand in each of the major consuming sectors, highlights the trend away from oil in uses where fuel substitution opportunities are available. Oil demand is expected to decline in three of the four sectors as electricity, direct coal burning and, to a lesser extent, gas meet incremental demand and displace some oil from some of its current uses.

OIL AS PERCENT OF TOTAL ENERGY DEMAND IN THE INDUSTRIAL COUNTRIES, BY SECTOR

	1979	2000
Electric Power Generation	18	1
Industrial	34	19
Residential and Commercial	39	25
Transportation	99	99

It is in the transportation sector that little inter-fuel substitution is expected during the balance of this century. Oil's share is likely to remain at more than 99 percent despite the advent of electric cars in the late 1980s. Substantial efficiency improvements, however, are expected to hold growth in total transportation fuel requirements in the major industrial countries to less than ½ percent per year during the outlook period.

Oil is projected to remain the world's single largest source of energy during the period to 2000. Chart 13 shows projected oil supplies, including crude oil production, liquids recovered from natural gas (NGL), synthetic liquid fuels and very heavy oil.

The capacity to produce crude oil is limited by the availability of discovered reserves, reservoir characteristics and the rate at which new reserves are found and developed. In addition, an increasing number of governments are adopting policies which limit production rates, particularly for export. The combination of these factors is expected to limit the increase in worldwide production of crude oil and NGL to an average of only ½ percent per year through 2000. Total output over the period will increase about 5 million barrels per day from the 1979 level of 66 million barrels per day.

In the United States, crude oil and NGL production is expected to decline from 10 million barrels per day in 1979 to 7 million barrels per day in 1990, but then to increase slightly to about 7½ million barrels per day by 2000. Production from new discoveries in frontier areas and increased application of enhanced recovery methods are expected to more than offset production declines from existing fields in mature areas during the 1990s.

Canadian crude oil and NGL production is expected to decline from 1¾ million barrels per day in 1979 to less than 1½ million barrels per day by 1990. Development of new fields off the Atlantic Coast and in the Beaufort Sea are expected to stabilize oil production in the 1990s. Deep water and frigid climates, however, mean that the production costs of these new sources will be high and that the lead times to the start of commercial production will probably range from 6 to 13 years. Canadian government tax and energy policy decisions are likely to have a major impact on the level and sources of future production. This Outlook does not reflect the impact of the national energy program proposed in the Fall of 1980 by the Canadian government. However, preliminary assessments suggest that production levels might be well below those included in the Outlook.

Near-term production increases are expected in Europe from the continued development of the North Sea. Production in other non-OPEC countries, primarily developing countries, is anticipated to more than double during the outlook period, increasing from 6 million barrels per day in 1979 to 13 million barrels per day by 2000.

Countries with significant production growth potential include Norway, Brazil, Mexico, and Malaysia. Government policies regarding exploration, development, and production will determine how much of this potential becomes available.

OPEC production, including NGL, is projected to fall within a 28 to 33 million barrels per day range (26 to 30 for crude oil alone) during the outlook period. Production policies of various governments are highly uncertain. Even a constant crude oil production rate would mean a significant decline in exports because of increased oil consumption within the producing countries themselves.

Production in the Centrally Planned Economies is projected to expand at an average rate of less than 1 percent per year and remain at about 20 percent of world oil supply. The USSR, the world's largest producer of crude oil, accounts for about three-fourths of total CPE oil production. Net CPE oil exports to the rest of the world are expected to decline from about 1¼ million barrels per day in 1979 to about 500,000 barrels per day by 2000.

Liquids from synthetics plants and very heavy oil will begin to appear in appreciable quantities in the 1990s, and by 2000 are expected to exceed 6 million barrels per day.

As the bar at the right of Chart 13 shows, more than one-third of total oil production in 2000 is expected to come from oil reserves yet to be discovered. Virtually all of the estimated synthetic fuels volume will have to come from facilities yet to be built.

CHART 13

WORLD OIL SUPPLY

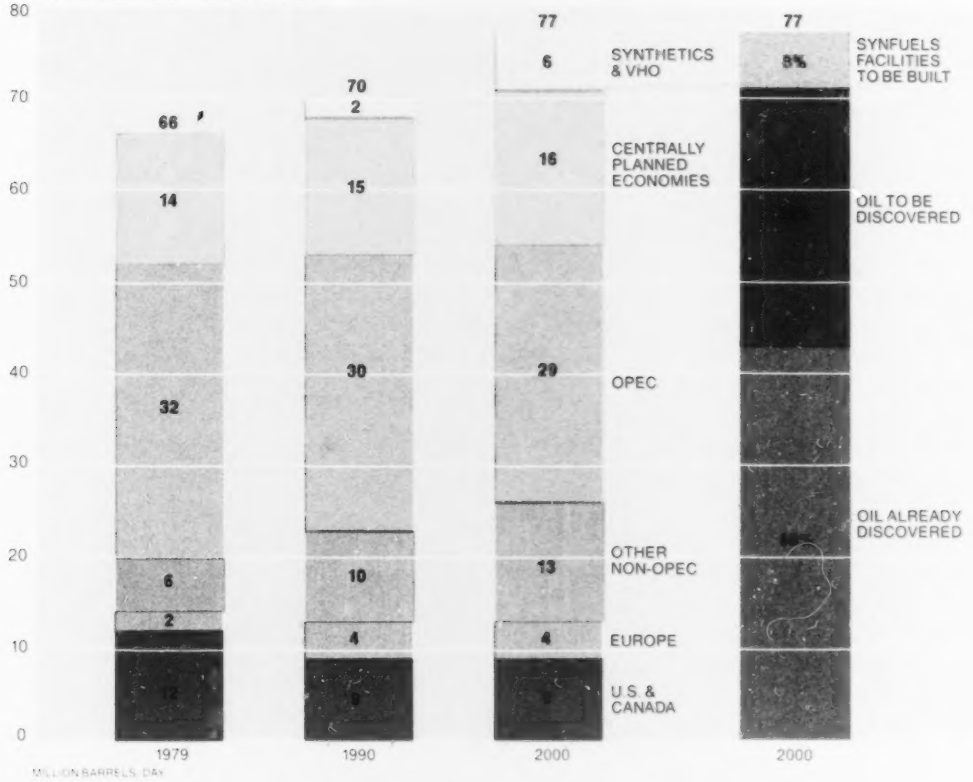
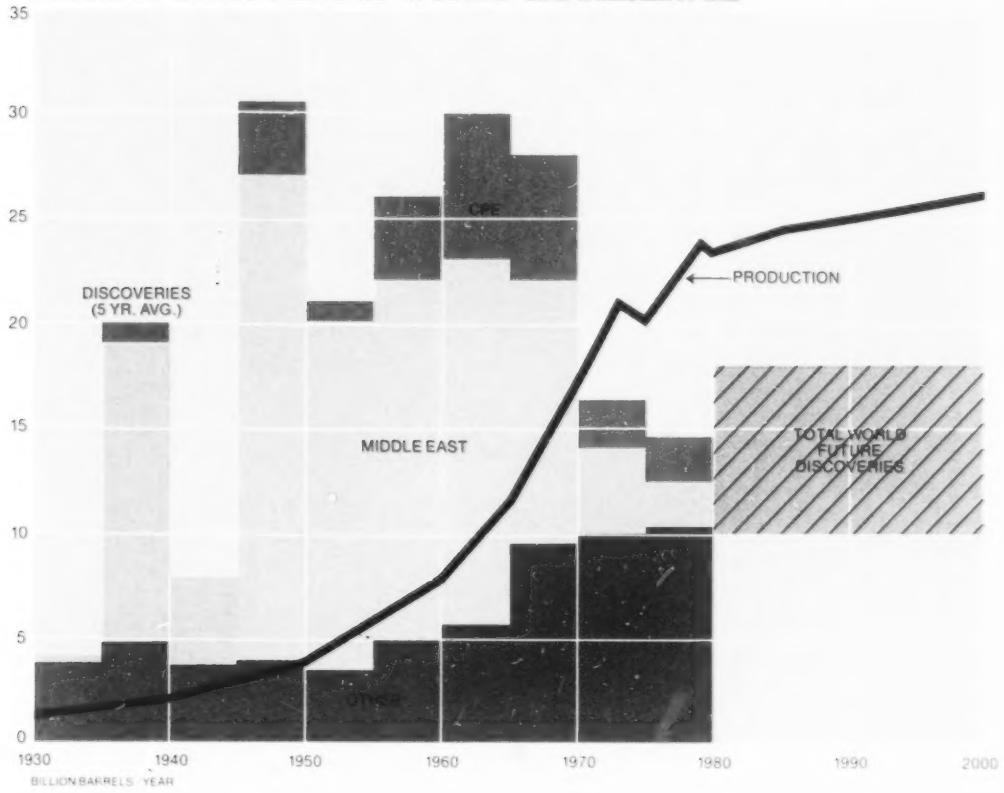


CHART 14

RATE OF DISCOVERY OF WORLD OIL RESERVES



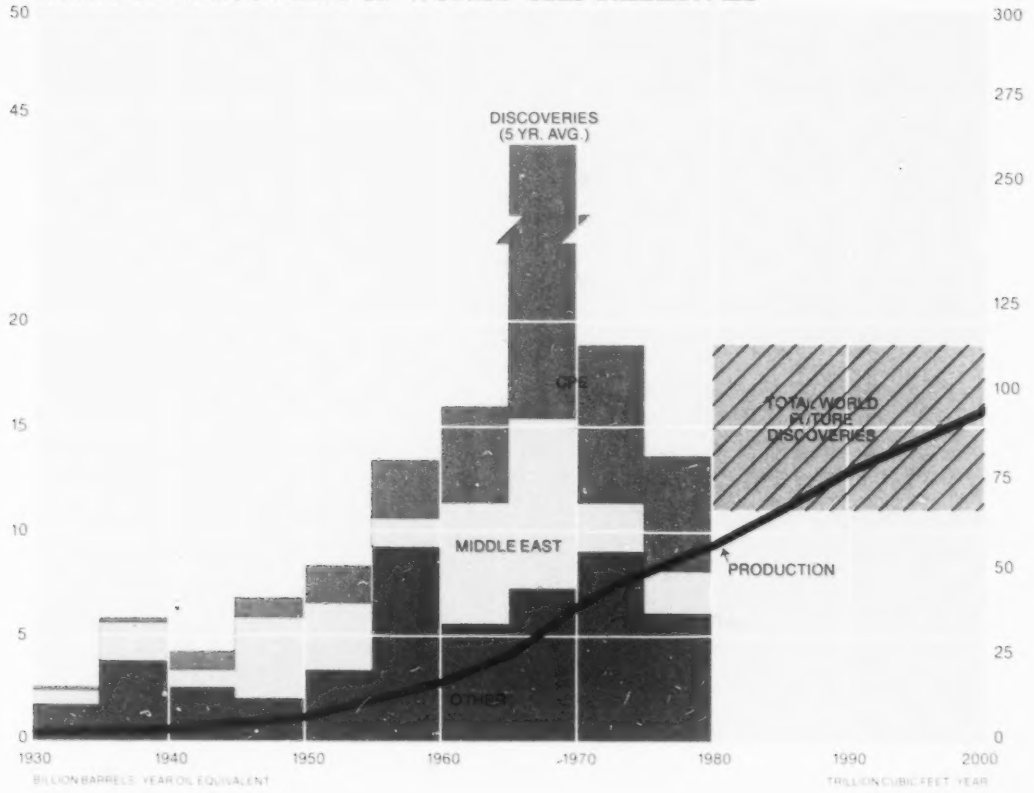
For some years now, the world has been consuming more oil than it has been finding. During the quarter of a century prior to 1970, substantial discoveries, principally in the Middle East, had built the world's inventory of discovered reserves, as illustrated in Chart 14. In the early 1970s, however, the situation reversed. Smaller discoveries and a continuing rise in oil production caused the inventory of discovered reserves to decline. This pattern is expected to continue in the future, despite a much slower rate of growth in oil consumption and the increased incentives to discover oil provided by rising energy prices.

There is little doubt that finding and developing the world's as yet undiscovered oil reserves will be progressively more difficult and costly. Many prospects are in remote locations or harsh operating environments, such as the Arctic, which will be technologically demanding and will require long lead-times for development. Fields remaining to be discovered in areas where production already exists are anticipated to be somewhat smaller, on average, than past discoveries. Moreover, the number of unexplored areas is steadily diminishing.

Thus, even with an active exploration effort, the average oil discovery rate for the outlook period is likely to be well below the expected production of 24 to 25 billion barrels per year and, consequently, the world's inventory of discovered oil reserves will continue to decline. Since production cannot increase indefinitely in the face of declining discovered reserves, it seems reasonable to expect that conventional oil production will reach a plateau some time shortly after the turn of the century.

CHART 15

RATE OF DISCOVERY OF WORLD GAS RESERVES



Historical data pertaining to gas discovery and consumption rates are less complete and less accurate than for oil, and there is greater uncertainty about the future. However, in contrast to oil, the gas discovery rate currently exceeds the gas production rate and it is anticipated that this relationship will continue through the end of this century, even with projected steady increases in gas production. This can be seen in Chart 15. The world is still building its inventory of discovered gas reserves and is not expected to begin liquidating this inventory for a number of years. The peak in gas production is unlikely to be reached until well into the 21st century.

Although prospects for finding large new discoveries are better for gas than for oil, most also are situated in remote locations or harsh operating environments. Moreover, they generally require deeper drilling than oil. As with oil, finding and developing the world's remaining gas resources will be costly, will take a good deal of time, and will be technologically demanding. Despite this, the availability of reserves is not expected to be a limiting factor during the outlook period. It is the development of major international gas transportation systems and the ability of producers and consumers to negotiate contracts that will determine the rate at which gas is utilized.

SYNTHETIC FUELS AND VERY HEAVY OIL OUTLOOK

Synthetic fuels and very heavy oil are projected to be important factors in the energy supply picture in the 1990s, but many large-scale projects must get under way in the early 1980s to achieve projected production levels. For purposes of this Outlook, synthetic fuels are defined to include shale oil, coal liquids and gases, alcohol, methanol or gasoline fuels from natural gas and gas fuels from liquids. Very heavy oil (VHO) is the term applied to oil whose primary production requires the use of heat or mining.

The only large-scale production today is in Brazil (alcohol), Canada (VHO), and South Africa (coal liquids). Synthetic fuels and VHO supplies are projected to reach almost 3 million barrels per day oil equivalent by 1990 and about 8 million barrels per day by 2000. As indicated in the table below, by 1990 synthetic fuels and VHO will account for a significant share of oil and gas demand in Brazil, Canada and Venezuela. By 2000, they are expected to become an important factor in meeting oil and gas demands worldwide.

SYNTHETIC FUELS AND VHO AS PERCENT OF OIL AND GAS DEMAND

	1990	2000
United States	5	18
Canada	15	17
Venezuela	30	55
Brazil	25	34
Australia	3	28
Others	1	2
World excluding CPE	4	9

The synthetic fuels and VHO production projected in this Outlook is feasible, provided government policies are reasonably favorable. With early elimination of constraints, production could be as much as 2 million barrels per day oil equivalent higher by 2000 than shown on Chart 16. On the other hand, in a more restrictive policy environment, world synthetic fuels output probably would be significantly lower. In this event, there is no obvious, practical alternative that could make up for the lost synthetic liquids production.

The United States is expected to lead in synthetic fuels development in the 1990s, because of its vast coal and oil shale resources as well as its need for alternatives to imported oil. Synthetic fuels production at these levels is within the financial and technological capability of the U.S. A number of synthetic fuels projects are already at the advanced planning stage.

Production from Canada's Athabasca heavy oil sands deposit is expected to make that country the leading producer of VHO through 1985. Expansion of existing plants and the addition of new plants are projected in this Outlook in the late 1980s, but the actual outcome will be highly dependent on government policies.

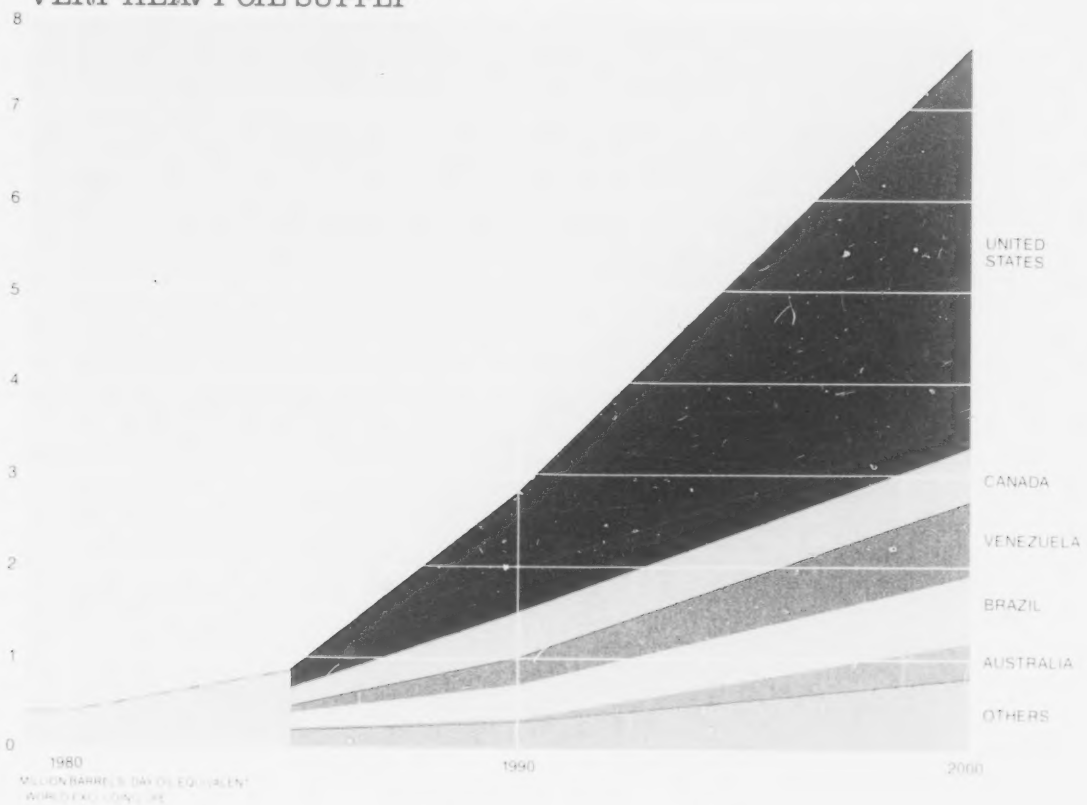
In Venezuela, the projections reflect the development of the Orinoco heavy oil belt, based on plans announced by the government.

Brazil is expected to continue to be the leader in alcohol production for motor fuel supplies. Alcohol from sugar cane currently accounts for close to 20 percent of Brazil's gasoline consumption, and the country has plans to increase that to 80 to 85 percent in the 1990s. By 2000, the synthetic fuels projection for Brazil will total about 750,000 barrels per day oil equivalent, about half shale oil and coal synthetics.

Through development of its substantial shale oil reserves, Australia also is expected to become a major synthetic fuels producer by 2000. The "Others" group includes projects in about a dozen countries, notably gasoline from natural gas in New Zealand, liquids and gas from coal in South Africa, and coal gasification in several European countries.

CHART 16

SYNTHETIC GAS AND LIQUID FUELS AND VERY HEAVY OIL SUPPLY*



Only limited information is available regarding synthetic fuels development in the CPE, therefore, no supply projection is included in this Outlook. Modest development is likely, however based on reported activities in oil shale and coal synthetics in both the USSR and the PRC.

Where resources are available and government policies and regulations permit development, a wide range of synthetic fuels processes are economic and will become increasingly so as technological improvements evolve and as energy costs continue to rise. However, the development of a synthetic fuels industry will create a number of complex economic and social problems. Such matters as infrastructure development, environmental protection and water use will require careful planning and coordination.

The capital requirements will be enormous. A 50,000 barrels per day synthetic fuel plant is estimated to require an investment in the $2 to 3 billion (1980 dollars) range. Worldwide, the outlook projection represents an investment of about $400 billion (1980 dollars) and employment of some 600,000 engineering, construction and operating people by 2000. Once a basic industry is established, continued development should result in these fuels supplying a still larger share of world energy demand after the turn of the century. Continued growth beyond 2000 would require even greater undertakings, a large number of which would also have to be started before the end of this century. Marshalling all these resources and integrating them into the economy without undue distortion will be a major task.

With continued technological development, renewable energy sources, such as solar and eventually nuclear fusion, will in all likelihood become major supply sources in the 21st century. Except for hydropower, however, the contribution of renewables to total energy supplies will be relatively small for the remainder of this century.

Chart 17 illustrates projected supplies of renewable energy sources other than hydropower. Although not shown here, hydropower accounts for more than 4½ percent of world energy supply at present and is projected to increase to 6 percent by 2000. (Hydropower is included in Chart 4.)

In this Outlook, solar energy is defined as energy produced from commercially traded solar collection equipment for generating domestic space heat, hot water, industrial heat or electricity. The solar energy captured by rooftop water tanks or other homemade devices that are popular in some parts of the world, as well as that from "passive" sources, is not included. However, to the extent that it replaces other forms of commercial energy, such unmeasurable solar does reduce the overall energy demand shown in the Outlook.

Some solar technologies are economic today in certain applications and locations. With the tax credit provided in the United States today, residential solar water heating is attractive to users in some areas, but generally only if competing with relatively high cost energy, such as electric water heating.

Photovoltaic electricity, the direct conversion of sunlight to electricity, cannot compete currently with central power grids but is economical at remote installations where the alternative is batteries or small diesel-driven generators. Although such installations may provide rapid growth for the photovoltaic industry, photovoltaics are not likely to be a significant part of total energy supply until technological advances reduce costs to a tenth or less of current levels. The impact of such a breakthrough is not assumed in this Outlook.

Even the modest contribution of solar energy projected in the Outlook requires that a substantial number of homes and commercial facilities use solar heat or hot water over the next two decades. Five million homes in the U.S. are assumed to have solar domestic hot water systems and about 2½ million to have solar heating systems by 2000. About twice this number of installations are projected for outside the United States, principally in Europe, Canada and Japan.

Wind, wave and tidal power conversions to electricity are projected to contribute less than 100,000 barrels per day oil equivalent by the turn of the century.

Alcohol fuels from biomass, which are included in the synthetic fuels outlook, are projected at about 500,000 barrels per day in 2000, reflecting principally Brazil's program to develop an automobile fleet fueled by ethyl alcohol and anticipated increased use of gasohol in the U.S.

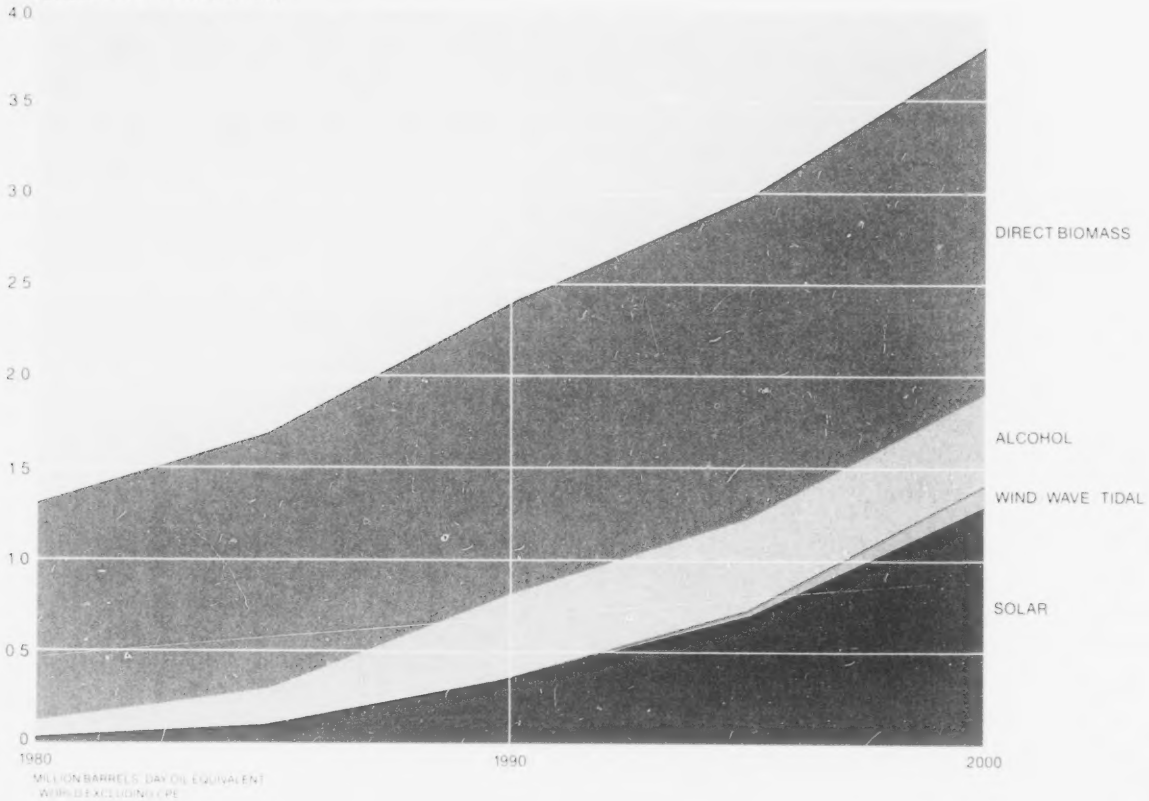
Direct fuel use of biomass in the industrial sector is principally in the form of wood wastes burned as fuel in the production of paper and wood products in the industrial countries. In some less-developed parts of the world, direct use of biomass fuels, including firewood, dung and crop residues, is often a major source of energy supply for basic personal needs such as heating and cooking. These supplies generally are not commercially traded. There are no reliable data on the extent of biomass fuel use. Consequently, no estimates of direct biomass use, either commercial or non-commercial, are included in the overall energy supply/demand balances presented in this Outlook. However, this chart on renewable energy supply does provide some indication of the magnitude by which direct biomass use reduces the need for other commercial energy forms in the industrial sector.

The total contribution of the renewable energy sources shown on the chart will increase from more than 1 million barrels per day oil equivalent today to almost 4 million barrels per day by 2000, when they would be equivalent to almost 2 percent of world energy supplies.

CHART 17

RENEWABLE ENERGY SUPPLY*

(EXCLUDING HYDROPOWER)



MILLION BARRELS DAY OIL EQUIVALENT

* WORLD EXCLUDING CPE

In the United States, a reduced rate of growth in total energy demand is expected to accompany an accelerated transition to greater diversity in energy supplies. The outlook is based on real GNP growth of about 2½ percent per year between 1979 and 2000, compared to more than 3½ percent per year in the 1965 to 1973 period.

Energy demand is projected to grow almost 1 percent per year, only about a fifth as rapidly as in the 1965 to 1973 period. The rate will accelerate somewhat during the second half of the outlook period, rising from less than 1 percent per year in the 1980s to a bit more than 1 percent per year in the 1990s. The modest increase in the 1990s primarily will reflect the development of the highly energy-intensive synthetic fuels industry. Total energy consumption by 2000 is expected to be about 46 million barrels per day oil equivalent, compared to 39 million barrels per day in 1979.

During the last several decades, oil and natural gas have been the dominant fuels in the U.S. For the rest of the century, however, use of these fuels is expected to decline significantly, falling from about three-fourths of the total in 1979 to about one-half by 2000 as illustrated in Chart 18. Nuclear, hydropower and coal will provide virtually all the growth in energy demand and replace oil and gas in many uses.

Nuclear's share of total energy supply is projected to increase from 3 percent in 1979 to 11 percent by 2000. Increasing at a 6½ percent annual rate—more than six times that for total energy—nuclear energy is expected to provide nearly 5 million barrels per day oil equivalent by 2000. Generating capacity projected for 1990 is either currently operating or under construction, and is consistent with delays announced by utilities.

Hydropower, geothermal, and solar energy will increase their combined share of total energy supply from 4 percent in 1979 to 6 percent in both 1990 and 2000. Most of this will come from hydropower. New investments, largely in low-head facilities and other small projects, will increase hydropower supply to about 2½ million barrels per day oil equivalent by 2000.

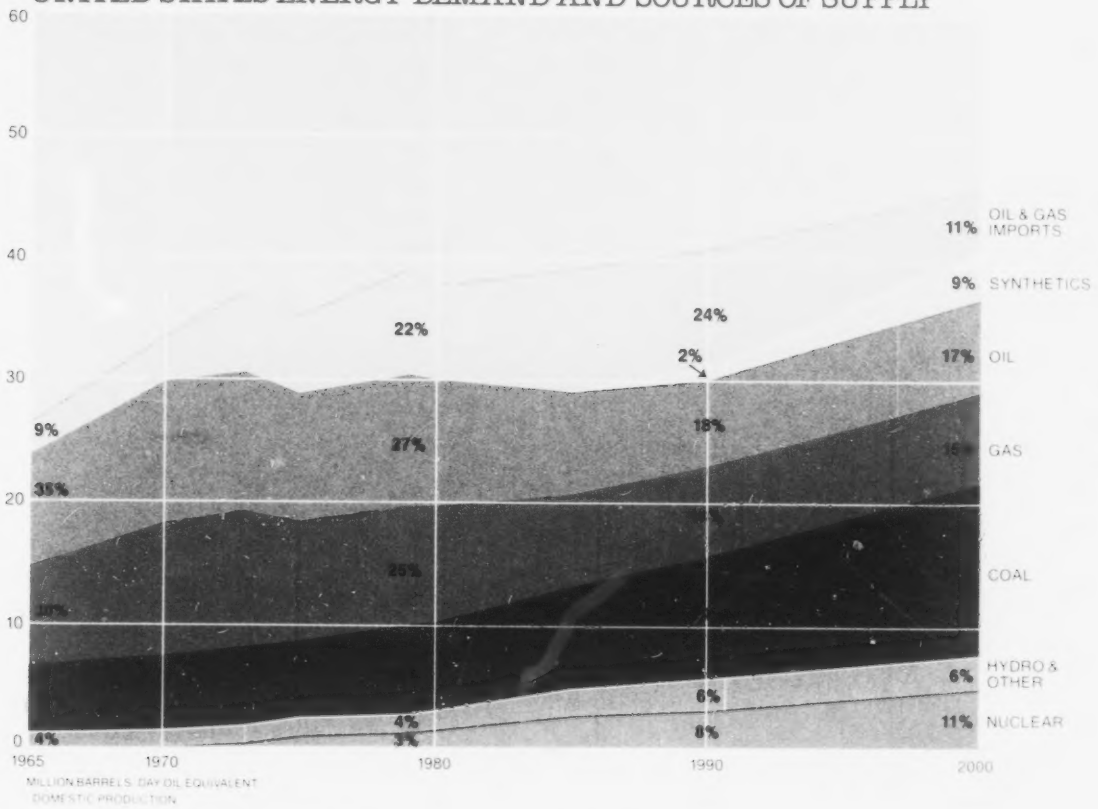
Coal's share of total energy supply for domestic consumption is expected to increase substantially, rising from 19 percent in 1979 to 31 percent by 2000. U. S. coal consumption is expected to nearly double by 2000 to about 14 million barrels per day oil equivalent, including 2 million barrels per day consumed in the production of synthetic fuels. (In this Outlook, the volumes of gas and liquid fuels produced from coal synthetics projects, which will rise to about 2½ million barrels per day oil equivalent by 2000, are included in the synthetics fuels category.) Utilities will account for almost two-thirds of coal demand growth other than synthetic fuels needs. The other third will be mainly for large industrial boilers, in which coal use is more economic than oil or is mandated by government policy.

The share of total energy supplied by gas is seen declining from 27 percent in 1979 to about 19 percent by 2000. Gas is being replaced rapidly in electric power generation and large industrial boilers, and future consumption is expected to be concentrated in residential, commercial, small industrial and non-energy uses, such as petrochemical feedstocks. To meet these demands, domestic production, which is projected to decline 20 percent during the outlook period, will be augmented by growing import volumes during the 1980s. The latter are expected to increase from 600,000 barrels per day oil equivalent in 1979 to about 1 million barrels per day by 1990. Thereafter, imports are projected to decline to roughly the current level as coal and synthetic gas replace natural gas in various markets. About one-half of year 2000 conventional natural gas production is expected to come from new discoveries.

Oil use is expected to decline rapidly in the industrial, residential and commercial sectors and in electricity generation, replaced primarily by coal and nuclear. However, acceptable substitutes are not available for oil in all uses. Oil remains the only significant transportation fuel and is still required for many non-energy uses, such as lubricants and solvents. Although significant efficiency improvements are expected in the transportation sector, and electric vehicles of limited range are likely to become available in the late 1980s, a substantial demand for liquid fuels for transportation and other specialized uses will continue to exist.

CHART 18

UNITED STATES ENERGY DEMAND AND SOURCES OF SUPPLY



Domestic production of crude oil and NGL is projected to decline from 10 million barrels per day in 1979 to 7 to 8 million barrels per day in the 1985 to 2000 period. Declining production from onshore areas in the contiguous 48 states will be only partially offset by projected increases in frontier production.

Production of synthetic oil and gas from coal and oil shale is expected to reach about 1 million barrels per day oil equivalent by 1990, increasing to 4 million barrels per day, or 9 percent of total energy supply, by 2000. This Outlook assumes a major national commitment to synthetic fuels, in line with announced government goals for 1990.

Even with the rapid development of synthetic fuels production, net oil imports are projected to increase from the 1979 level of about 8 million barrels per day to a peak of about $8\frac{1}{2}$ million barrels per day in 1985. Rising synthetic liquids production in the 1990s, however, will permit a decline in net oil imports to about 4 million barrels per day by 2000. To the extent that synthetic liquids production falls short of these projections, imports might be increased. However, should these be unavailable or prohibitively expensive, energy use in specialized applications could well be lower than projected, adversely affecting economic growth.

Energy demand in Western Europe is projected to increase 1½ percent per year, less than one-third the pre-1973 rate and significantly slower than the 2½ percent per year growth rate projected for real GNP. Total energy demand is projected to rise from 27 million barrels per day oil equivalent in 1979 to about 37 million barrels per day by 2000.

Nuclear, continuing as the most rapidly growing major component of energy supply, is projected to increase its share from 3 percent of total energy requirements in 1979 to 16 percent by the year 2000, as Chart 19 illustrates. Environmental and political difficulties remain in some countries, but constraints are expected to be eased in others. France continues to place the highest priority on nuclear energy in its energy policy. Nuclear will account for about two-thirds of its electricity generation requirements by 2000, a much higher proportion than in any other country in the world.

Coal is expected to provide a significant share of energy growth and replace oil in many uses, particularly in industry and in electric power generation. Local coal production is projected to grow only 1 percent annually to 2000, slightly less than the rate of energy demand growth. But coal imports—from the CPE, South Africa, the U.S., Australia and South America—are expected to quadruple from 1 million barrels per day oil equivalent in 1979 to about 4 million barrels per day by 2000, supplying most of the increase in consumption.

Gas production, particularly in the Netherlands and West Germany, is expected to peak in the mid-1980s and then to decline, offset partially by increased Norwegian North Sea production. By 2000, about 5 percent of Europe's gas supplies will come from coal gasification projects. The biggest increment to supplies, however, will come from imports, principally from the USSR, North Africa and the Middle East. These are expected to rise substantially, from about 600,000 barrels per day oil equivalent in 1979 to 3 million barrels per day by 2000, and to contribute importantly to growth in the industrial, residential and commercial sectors.

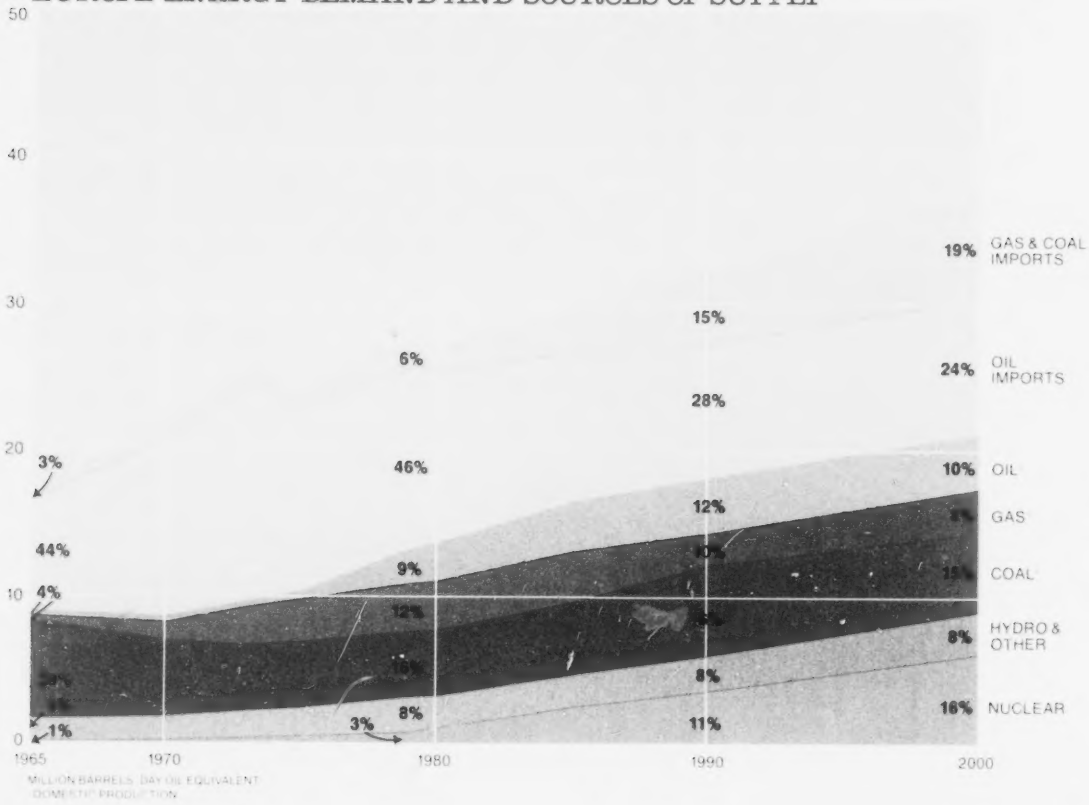
Oil production is projected to expand through the 1980s and reach a plateau in the 1990s. Over much of this period, North Sea production rates are likely to be limited by national energy policies in the United Kingdom and Norway.

Oil demand, meanwhile, is expected to decline from almost 15 million barrels per day in 1979 to about 13 million barrels per day by 2000. Although demand for oil in transportation and some other specialized applications will continue to grow, even more oil will be displaced from other sectors by nuclear, coal and gas. As a result, oil import requirements are expected to decline from almost 13 million barrels per day in 1979 to just over 9 million barrels per day by 2000. The share of oil in total energy consumption is projected to fall from one-half to one-third.

Total fossil fuel imports will decline from 52 percent of all energy consumed in 1979 to 43 percent by 2000. The composition, moreover, will be more diversified. As dependence on imports for oil declines, that for coal and gas will rise. The latter two fuels, coming from a variety of sources, are expected to account for almost half of future energy imports, compared with only 11 percent in 1979.

CHART 19

EUROPE ENERGY DEMAND AND SOURCES OF SUPPLY



Between 1979 and 2000, Japan's energy demand is projected to increase 2 percent per year, about half the expected growth rate of real GNP. Over the 1979 to 1990 period, essentially no growth is expected in oil demand, and in the 1990s, it is projected to decline at about ½ percent per year.

The projected growth in energy demand—from 7½ million barrels per day oil equivalent in 1979 to about 11½ million by 2000—will be met through the increased use of coal, gas and nuclear energy. The increasing substitution of these fuels for oil in industrial and power generation facilities is expected to reduce Japan's dependence on imported oil over the outlook period, but oil will still account for more than 40 percent of Japan's energy use in 2000. If conservation, energy efficiency improvements, structural shifts in the economy, and the substitution of alternate fuels proceed as expected, 1979 will have been the peak year for Japanese oil imports.

As Chart 20 shows, Japan remains a nation with very limited domestic supplies of energy. Hydropower and small amounts of indigenous fossil fuels are expected to provide only 8 percent of total supply. Reflecting efforts to minimize oil imports, nuclear energy is expected to grow rapidly from about 250,000 barrels per day oil equivalent in 1979 to about 2 million barrels per day by 2000. By the latter date, it will provide 18 percent of total energy supply. In electric power it will be still more important, its share of generating capacity rising from 12 percent in 1979 to almost 50 percent by 2000.

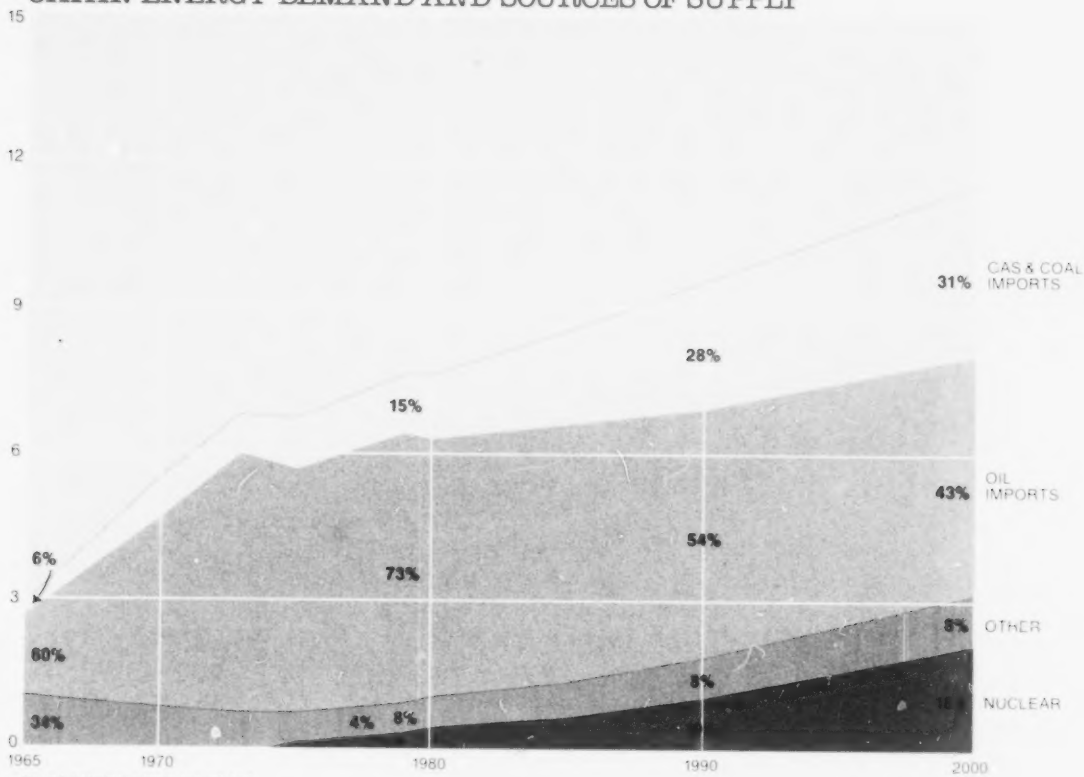
LNG imports are expected to increase from about 350,000 barrels per day in 1979 to almost 1½ million barrels per day by 2000, largely for use in electric power generation. Japan is the only major industrial country which plans to increase gas use in the electric utility sector, with gas-fired capacity increasing from 13 percent of the total in 1979 to about 20 percent by 2000. This Outlook does not include any major synthetic fuels projects in Japan; however, the production of synthetic gas from coal might be an alternative to some of the projected LNG imports.

Imports of metallurgical and thermal coal are expected to increase from less than 1 million barrels per day oil equivalent in 1979 to more than 2 million barrels per day by 2000. In Japan, the steel industry continues to be the major coal consumer, but coal consumption is expected to increase in all sectors. Coal is expected to account for 15 percent of electricity generating capacity by 2000 compared to 4 percent in 1979. Continued growth in coal use in the industrial sector will be limited principally by site availability for coal handling and scrubbing equipment.

The rapid penetration of nuclear, gas and coal is expected to hold Japanese oil imports at a relatively constant level of about 5 million barrels per day through 2000. The share of imported oil in total Japanese energy supplies will decline substantially, from almost three-fourths in 1979 to less than 45 percent by 2000. Nevertheless, oil will remain the major fuel in Japan for the balance of the century.

CHART 20

JAPAN ENERGY DEMAND AND SOURCES OF SUPPLY



MILLION BARRELS DAY OIL EQUIVALENT

HYDROPOWER AND DOMESTIC FOSSIL FUELS PRODUCTION

Economic growth in the USSR, Eastern Europe and the People's Republic of China is expected to increase about 3 percent per year, significantly lower than the 1965 to 1979 rate. Energy demand is projected to increase $2^1/_2$ percent per year, about half the historical rate, rising from about 40 million barrels per day oil equivalent in 1979 to almost 70 million barrels per day by 2000. The USSR will continue to account for more than half of total energy demand in the CPE. The PRC's share is projected to increase slightly, while Eastern Europe's will decline.

Chart 21 shows domestic energy supply over the outlook period. Coal, accounting for almost half at present, is expected to increase only 2 percent per year, with the growth distributed roughly equally among the USSR, Eastern Europe and the PRC. Coal production in Eastern Europe is limited by reserves, while development of large resources in the USSR and PRC is hampered by high costs and by infrastructure, technology and mechanization limitations.

Nuclear energy is expected to grow rapidly, but from a low base. The share of nuclear in total CPE supplies is projected to grow from 1 percent in 1979 to about 9 percent by 2000. Two-thirds of the year 2000 capacity will be in the USSR and almost all the rest in Eastern Europe. Hydropower is likely to grow modestly, reaching 4 percent of supplies by 2000. Siberia has large hydropower potential, but sites near industrial centers in European Russia and in Eastern Europe are largely developed.

Gas is expected to be a major source of energy growth in the CPE, based primarily on large Siberian gas reserves in the USSR. Gas production is projected to increase more than 4 percent per year in the USSR, supplying not only domestic requirements, but also export markets in Eastern and Western Europe. The USSR share of total gas production in the CPE will increase from 85 percent in 1979 to more than 90 percent by 2000. The PRC also appears to have a significant gas resource base. Production, which currently accounts for only 5 percent of total CPE supplies, is expected to triple by 2000. However, it still will account for only about 7 percent of total CPE gas supplies in that year. All of the PRC production is expected to be consumed locally.

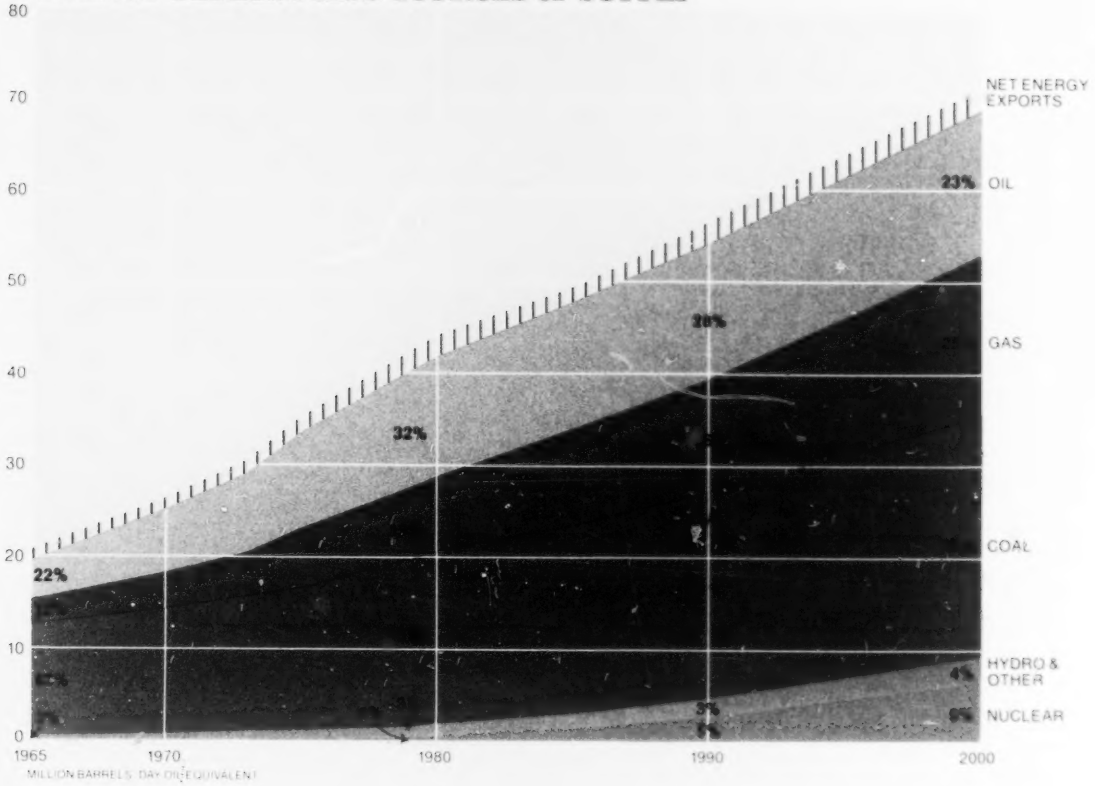
Oil production in the CPE is projected to increase less than 1 percent per year. Output in the USSR will be relatively stable, in the 11 to 12 million barrels per day range through 2000. The principal growth is expected to be in the PRC, where production could increase to about 5 million barrels per day by 2000, from just over 2 million barrels per day in 1979.

Total energy exports from the CPE during the outlook period are projected to continue to exceed imports by about 2 to $2^1/_2$ million barrels per day oil equivalent. Significant changes are expected, however, in the composition and source of exports. Increases in Eastern Europe's net oil imports from outside the CPE are expected to offset growing volumes exported from the PRC, thus leaving the net oil balance with the rest of the world to be determined by Soviet exports. The latter are expected to decline from $1^1/_4$ million in 1979 to 500,000 barrels per day by 2000. This drop in net oil exports will be offset by increases in USSR net gas exports to 700,000 barrels per day oil equivalent and by increases in net coal exports, primarily from the PRC, to $1^1/_4$ million barrels per day oil equivalent. The net result will be a relatively constant level of total net energy exports.

Thus, while CPE energy demand and production will continue to represent a large proportion of the world total, energy interaction between the CPE and the rest of the world is expected to remain relatively small.

CHART 21

CENTRALLY PLANNED ECONOMIES
ENERGY DEMAND AND SOURCES OF SUPPLY



Over the next two decades, the developing countries are expected to account for much of the growth in world energy demand and virtually all of the growth in world oil demand. With their energy demand projected to grow more than 5 percent annually through 2000, the developing countries' share of total world energy demand will increase from 12 percent in 1979 to more than 20 percent by 2000. Their oil demand, projected to increase about 4 percent per year, will rise from 18 percent of the world total in 1979 to 33 percent by 2000.

Oil and gas are expected to supply almost two-thirds of the growth in energy demand in the developing countries. Coal, nuclear and hydropower will maintain a relatively small share of their total requirements. These trends are in marked contrast to those projected for the industrial countries.

Chart 22 and the table below indicate that there are substantial differences in the energy demand patterns of the 118 countries which make up this group.

DEVELOPING COUNTRIES ENERGY DEMAND GROWTH, PERCENT PER YEAR

	1965-1973	1973-1979	1979-2000
OPEC	12.7	7.9	6.3
Other Oil-Exporters	8.4	5.5	6.3
High-Growth Countries	9.1	6.6	4.6
Low-Growth Countries	3.7	3.2	3.7
Total	7.3	5.4	5.2

The 13 OPEC countries and 15 non-OPEC oil exporters are expected to account for more than 55 percent of the growth in the group's total energy requirements through 2000. Most of the increase will be in oil, with domestic consumption growing rapidly to support industrialization programs. These 28 countries are expected to account for 75 percent of the total increase in oil demand in the developing countries over the outlook period. Oil production will be supplemented by increasing consumption of domestic natural gas, particularly in Mexico, the Middle East and North Africa. Coal will be locally significant in a few countries, such as Nigeria and Indonesia, that have significant reserves.

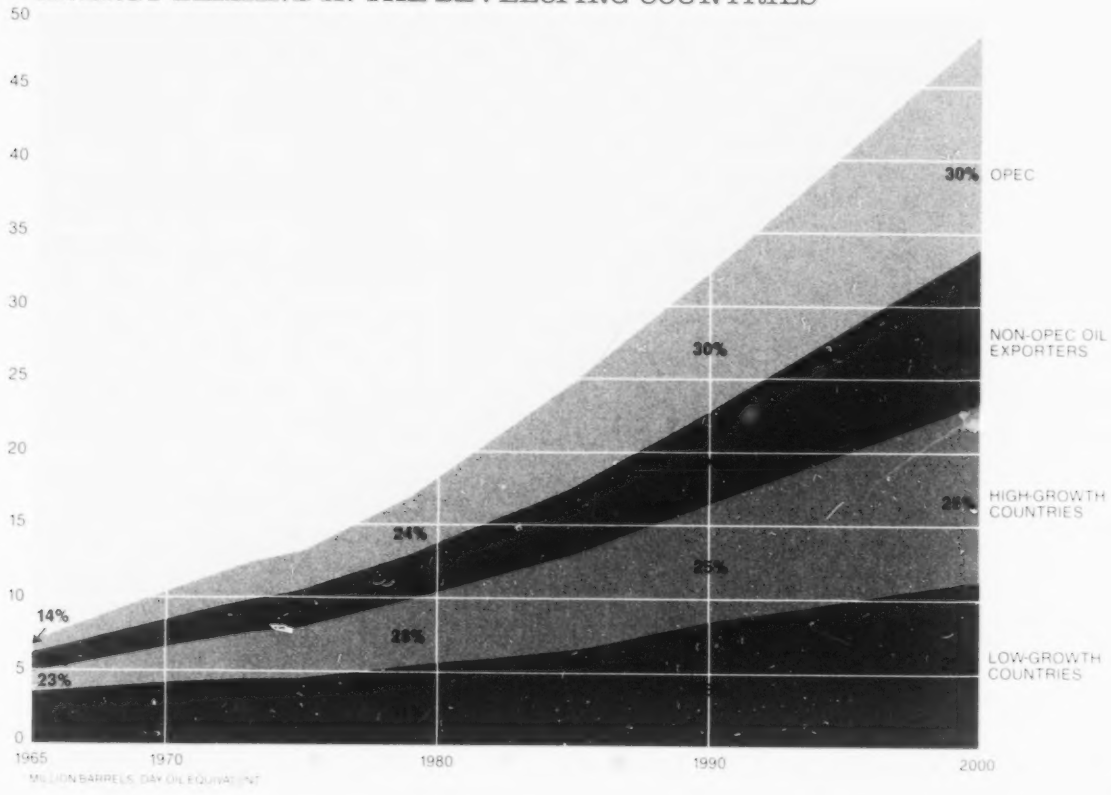
The 9 high-growth developing countries, all of which are oil importers today, will account for almost 25 percent of energy growth in the developing countries. Total energy demand for this group is projected to increase 4½ percent per year through 2000, but oil demand will grow only about 1½ percent per year. Most energy growth is projected to be supplied by coal, domestic and imported; it will be supplemented by gas, nuclear and, in Brazil, Colombia and Chile, by synthetic fuels. Many of these countries will face difficulty during the 1980s: in paying for oil imports, in managing debt service and in making massive domestic energy investments. After this difficult period, however, energy problems should ease as non-oil sources provide most of the growth.

Energy demand in the 81 low-growth countries is expected to increase about 4 percent annually; this group will account for only about 20 percent of growth in the developing world. Most of the increase in energy consumption is expected to be met by domestically produced coal, gas and oil, with small increases in imported oil. Total energy demand for the low-growth countries will account for less than 5 percent of the world total in 2000.

Most of the low-growth countries lack the resources and technological infrastructure necessary to develop synthetic fuels or the large central electricity grids required to make efficient use of nuclear energy. As a result, they are expected to remain dependent on conventional fuels at least for the rest of the century.

CHART 22

ENERGY DEMAND IN THE DEVELOPING COUNTRIES



Even though world energy demand is projected to grow at a much slower rate than in the past, the world will require 65 percent more energy by 2000.

Most of this increase must come from sources other than conventional oil, the supply of which is expected to increase only slightly and then to plateau shortly after the turn of the century. Coal, nuclear and gas are expected to be the major sources of the increase in energy supply. Renewables such as solar may contribute importantly in the next century, but they are not expected to be a major fuel source before then.

Liquid fuels are expected to be in tight supply and to be devoted increasingly to specialized applications, primarily transportation. In the 1990s, conventional oil will be supplemented by significant volumes of synthetic liquids, principally from oil shale and coal.

The transition to new energy use patterns and to a different mix of fuel supplies is achievable without abandoning other important social and economic objectives. But it will not be accomplished easily. Although the technology to achieve projected supply and demand levels is either proven or sufficiently close to commercial demonstration to suggest that it will not be a limiting factor, the translation of that technology into plant and equipment will be a massive undertaking. Moreover, the investments must begin soon if they are to have a significant impact in the 1990s.

The fundamental economic incentive to get the job done exists—for the investor to make the investments and for the consumer to switch energy forms and to reduce his total energy consumption. Whether the transition will occur more or less rapidly than suggested here, and with more or fewer problems, will depend to a considerable extent on the policies which governments around the world choose to adopt.

APPENDIX

COUNTRY GROUPINGS

For some aspects of the outlook analysis, the data have been aggregated for groups of countries. These country groupings are as follows:

Industrial Countries
OECD (excluding Turkey), Israel, South Africa

Centrally Planned Economies
USSR, Eastern Europe, PRC

Developing Countries
Oil-Exporting Countries
- OPEC (13 countries)
- Non-OPEC (Angola, Bahrain, Bolivia, Brunei, Burma, Congo, Egypt, Malaysia, Mexico, Oman, Peru, Syria, Trinidad, Tunisia, Zaire)

Other Developing Countries
- High-Growth (Argentina, Brazil, Chile, Colombia, Hong Kong, Singapore, South Korea, Taiwan, Uruguay)
- Low-Growth (All other countries)